Chapter 2

Outline of Syrian Arab Republic

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2.1 Outline of country and present status of social and economics

2.1.1 Country

Syria is located between 32 to 37 degrees of the north latitude in northern part of the Arabian Peninsula. The length of border is about 2,400km shared with Turkey, Iraq, Lebanon, Palestine, Jordan and only about 200km faced Mediterranean Sea.

Syria is social republic and its total land area is about 185,180km^2, which is almost half of Japan. According to the statistical data on 1998, the total population is estimated as 17.5 million, the population of capital Damascus is about 2.8 million and more than 90% of total population is Arabic. The average annual growth rate is over 3%. An averaged age is 21.4, population of less than 10 years old shares 30%

The climate of Syria is changed from the Mediterranean climatic zone of western part to desert zone. In coastal area, dry and hot summer and wet and warm winter. On the other hand, in dry area, climate changes from extremely hot and dry summer to cold winter.

In this chapter, the outline of economics and electrification etc of Syria will be mentioned.

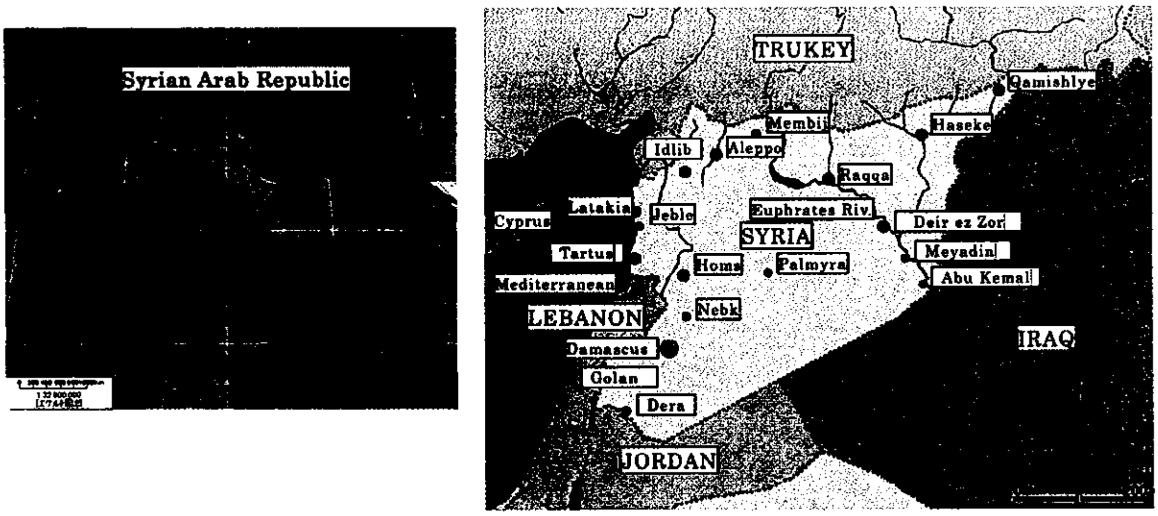

Fig.2.1-1 Map of Syria

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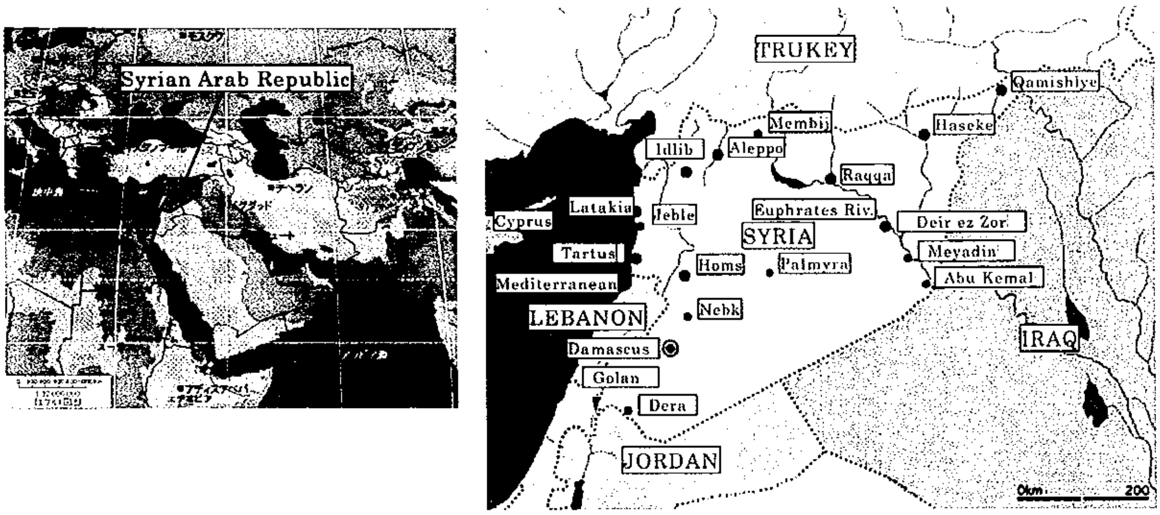


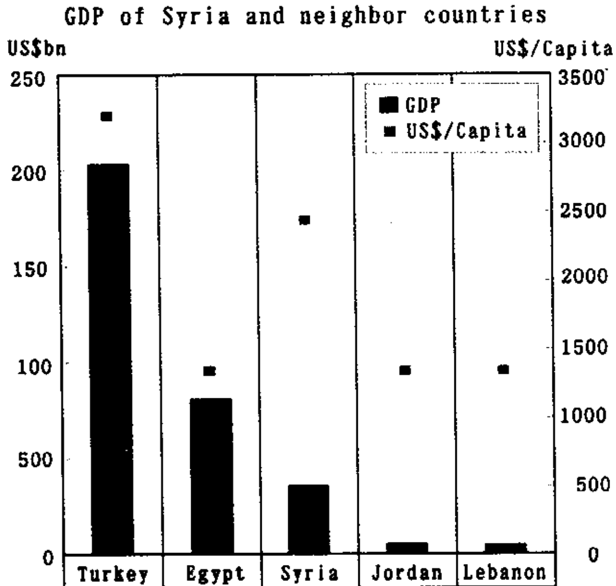
Fig.2.1-1 Map of Syria

2.1.2 Administrative organization

Administrative organization of Syria is consisted of Damascus city and 13 of Mofahazats. 13 of Mofahazats also divided into smaller administrative units that are called Mantikas, Nahias, Medina (city), Balda (town) and Karia (village). The site of this project belongs the prefecture of Aleppo, which is one of Mofahazats and the city of Aleppo is Medina.

2.1.3 Economy and industry

According to the statistical data, the industrial structure of Syria is as follows. First, when Syria is compared, in GDP, with its neighbor countries, GDP of Syria is about one half of Egypt, and Syria is second in GDP per capita to Turkey.



	Turkey	Egypt	Syria	Jordan	Lebanon
Population (Million)	63.8	60.3	14.9	4.4	4.1
Area (10^3 km^2)	775	1001	185	98	10

Source : IEA STASTICS(1996-1997)

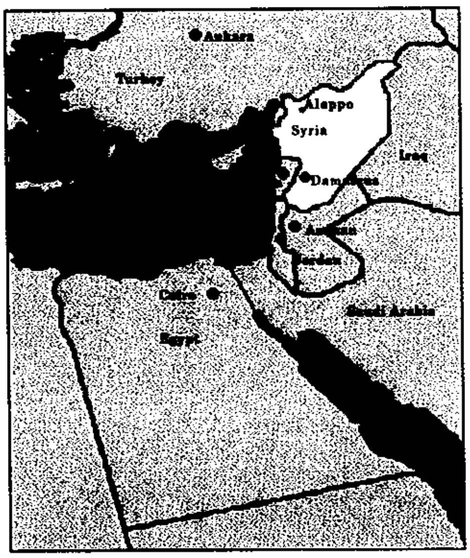
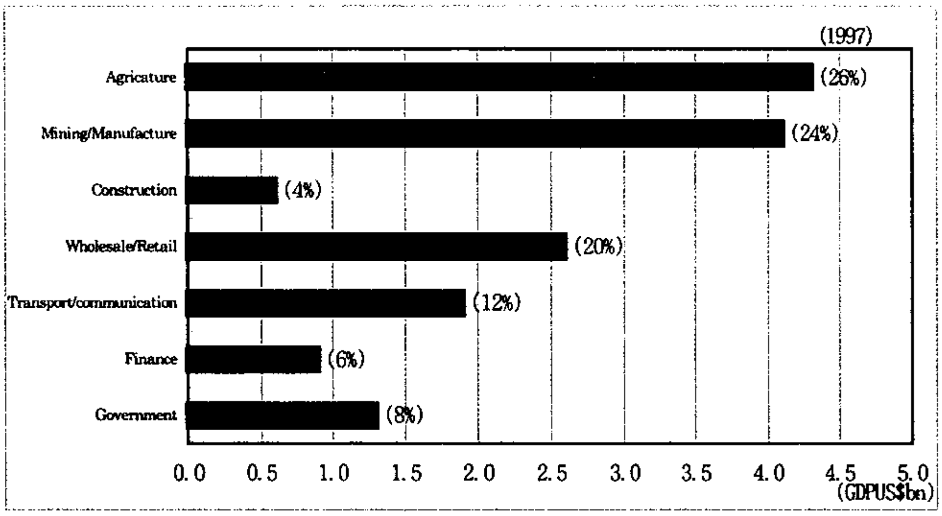


Fig.2.1-2 GDP of Syria and neighbor countries

The industrial structure of Syria is indicated as follows by the breakdown of GDP by sector. Agriculture accounts for 26 %, retail and wholesales trades 20 %, and mining and manufacturing 14 %, respectively. Agriculture, being the main sector, produces wheat, barley, sugarbeet, cotton, and citrus fruits. In addition to them, productions of stock farming such as butter and cheese are also high.

In the industrial field, the textile and leather products are the highest in production, followed by metal products, processed foods, and chemical products, in this order. On the industrial production, in the important sectors such as food, drinks, chemical products, and textile, the productions of the public enterprises account for large percentages. In other sectors, the productions of private enterprises account for large percentages. Investments by sector are important in predicting the future trends of the industries. The investment by nonmetallic mining is the largest, followed by food processing and inland transportation.



Source : STATISTICAL ABSTRACT (1999)
(SYRIAN ARAB REPUBLIC Office of the Prime Minister Central Bureau of Statistics)

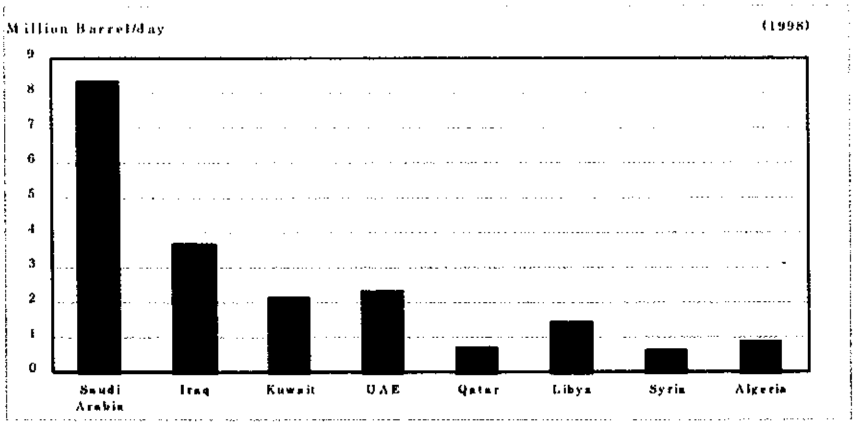
Fig.2.1-3 Breakdown of GDP of Syria by the sector

2.2 Condition of energy, agriculture and water

2.2.1 Energy conditions of Syria

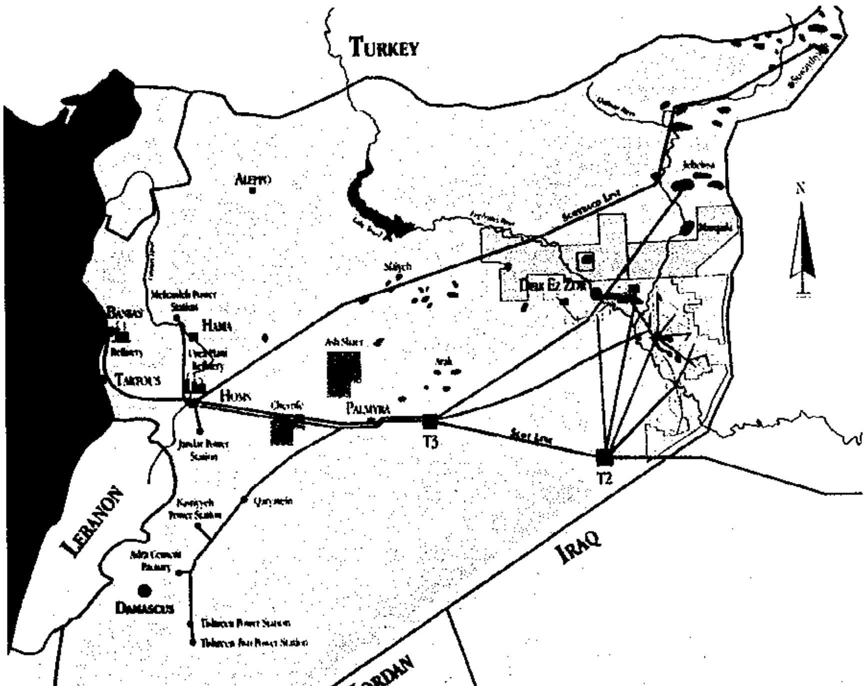
Production capacity of crude oil of Syria is relatively at a low level among the countries of the Middle East. Crude oil produced is mainly directed for export. The domestic energy consumption is mainly dependent on natural gas produced in Syria.

It is desired to develop new oil fields by promoting exploration of underground resources in future. The distribution of oil fields and gas fields and the routes of pipelines are as shown in Fig.2.2-1. The development of the infrastructure has already been extended to cover the entire national land.



Source : OIL & GAS JOURNAL (March 8, 1999)
(1998 Hughes Christensen Company)

Fig.2.2-1 Crude oil production capacity of the Middle East countries



Source : The Oxford Business Guide (1995-6)

Fig.2.2-2 Route of pipeline

2.2.2 Agricultural conditions

The agriculture of Syria is done in the coastal area, which has much rainfall, the plains of Damascus, Homs and Hama. In addition, the plain of Aleppo stretches northeast to Al Jazirah region between Euphrates and Tigris, which forms the Fertile Crescent.

①Characteristics of agriculture

The agriculture of Syria accounted for 26 % of GDP of 1997. About 25 % of the labor population engages in agriculture. Thus the agriculture is the largest industry that supports the Syrian economy. The greater part of the regional industries depends on the products of agriculture, and regional trade and export of agricultural products play important roles in the economy.

The major products include wheat, barley, cotton wool, beans, citrus fruits and beat. In recent years, the production of vegetables and fruits is gaining in importance, and tobacco is used for local markets. Cotton wool is a main cash crop of Syria. Export of animals such as sheep and cattle is important in the agricultural trade of Syria, in particular, in the gulf area.

With regard to the land use, about one half of the national land of Syria is available for agricultural production. However, the large dry area in the east of Syria cannot use for agriculture.

The greater part of the agricultural management is made by small-scale independent farmers who own about 57% of the national land. The remaining state land, that accounts for about 43% of the national land, is cultivated by farmers in joint management.

Rocky terrain in the south has been posing serious obstacles against modernization of agriculture. At present, with the assistance of foreign capitals, agricultural land reform projects are being executed every year, and much hope is placed on the expansion of agricultural land.

②Outline of irrigation

The quality of agricultural land is changed by the irregular and regional rainfall distribution. Except the coastal area of Mediterranean Sea and Al Jazirah region between Euphrates and Tigris, almost all of Syria, agricultural condition is significant changed by season. The harvest of agricultural products depends on rainfall and is not consistent.

About 32% of national land is possible area for agriculture. In resent years, for making effort to expand irrigation in Syria, about 92% of agricultural area has been developed. 22% of this developed land, irrigation facility is already set up. However, 78% of developed land depends on rainfall. In 68% of national land, which is not available for cultivation, 90% of this area is desert area or stockyard.

Table 2.2-1 Relation between irrigation area and rainfall

Distribution of Rainfall (mm)					
Annual Rainfall	>350	>300	>250	>200	<200
Area in Hectares	269	2,473	1,306	1,823	10,218
As % of Total Area	14.6	13.4	7.1	9.8	55.1

Source : Food and Agricultural Organization of the United Nations (FAO)

Cultivated/Irrigated Area (0000km²)					
Year	1994	1995	1996	1997	1998
Cultivable Lands	59.7	59.8	59.5	59.9	59.8
Cultivated Lands	54.8	55.0	54.7	55.2	54.8
Irrigated Area	10.8	10.8	11.2	11.6	12.1
% Irrigated	19.7	19.8	20.6	21.2	22.1

Source : STATISTICAL ABSTRACT (1999)
(SYRIAN ARAB REPUBLIC Office of the Prime Minister Central Bureau of Statistics)

③Roles of the government

Since 1987, the government has been gradually alleviating the traditional stringent control over agricultural products. For example, now the farmers are allowed to import an extensive range of products, such as agricultural machinery, transport machinery, chemical fertilizers, and seeds. Subsidies have been reduced, and prices and marketing of many products are subjected to market forces. The government, however, still holds the rights to set prices or monopolies of the stable food products. The farmers are allowed to sell some portion of their harvest in the free market. In the morning markets and along the roads, are sold vegetables, fruits, etc. that are brought in by trucks from the farmers of the surrounding areas. However, industrial products such as sugar beet and tobacco still remain under strict control by the government.

④Products

In the last three years, the agricultural products marked significant yields in most of the agricultural fields in Syria. In particular, grains and cotton wool marked the highest records of production, and vegetables and fruits showed steady increase in production. With green house cultivation that has been encouraged by the government, now farmers can produce agricultural products throughout the year. Chemical fertilizers are important means for increasing the production for the farmers.

Table 2.2-2 Yearly production quantities of agricultural products

Agricultural Output (Thousand Tones)					
Year	**1994**	**1995**	**1996**	**1997**	**1998**
Barley	1481.7	1705.1	1653.0	982.7	868.8
Wheat	3703.0	4184.1	4080.4	3031.1	4111.6
Cotton	535.4	600.1	760.0	1047.4	1017.8
Lentils	116.4	147.5	151.7	87.5	154.1
Chickpeas	25.2	53.5	45.7	58.9	84.6
Sugar Beet	1451.9	1406.1	974.2	1126.4	1202.2
Tabacco	14.3	23.4	18.1	16.8	21.7
Potatoes	362.4	471.0	439.1	265.5	492.3
Tomatoes	425.9	426.5	409.1	407.1	560.8
Citrus Fruit	619.2	365.8	696.0	550.0	741.0
Grapes	362.4	384.0	540.1	451.7	590.0
Apples	224.2	224.0	301.9	356.2	362.0
Olives	517.9	423.4	647.6	403.0	785.0

Source : STATISTICAL ABSTRACT (1999)
(SYRIAN ARAB REPUBLIC Office of the Prime Minister Central Bureau of Statistics)

⑤Agricultural trade

The above-mentioned successes in the agricultural fields have been reducing the import of foods by the pressure of the drastic increase in the population of Syria. Syria is maintaining the self-sufficiency for most of the grains, vegetables and fruits. However, considerable quantities of sugar and seed corn are imported. The imports of agricultural products account for about 7 % of the total import of Syria.

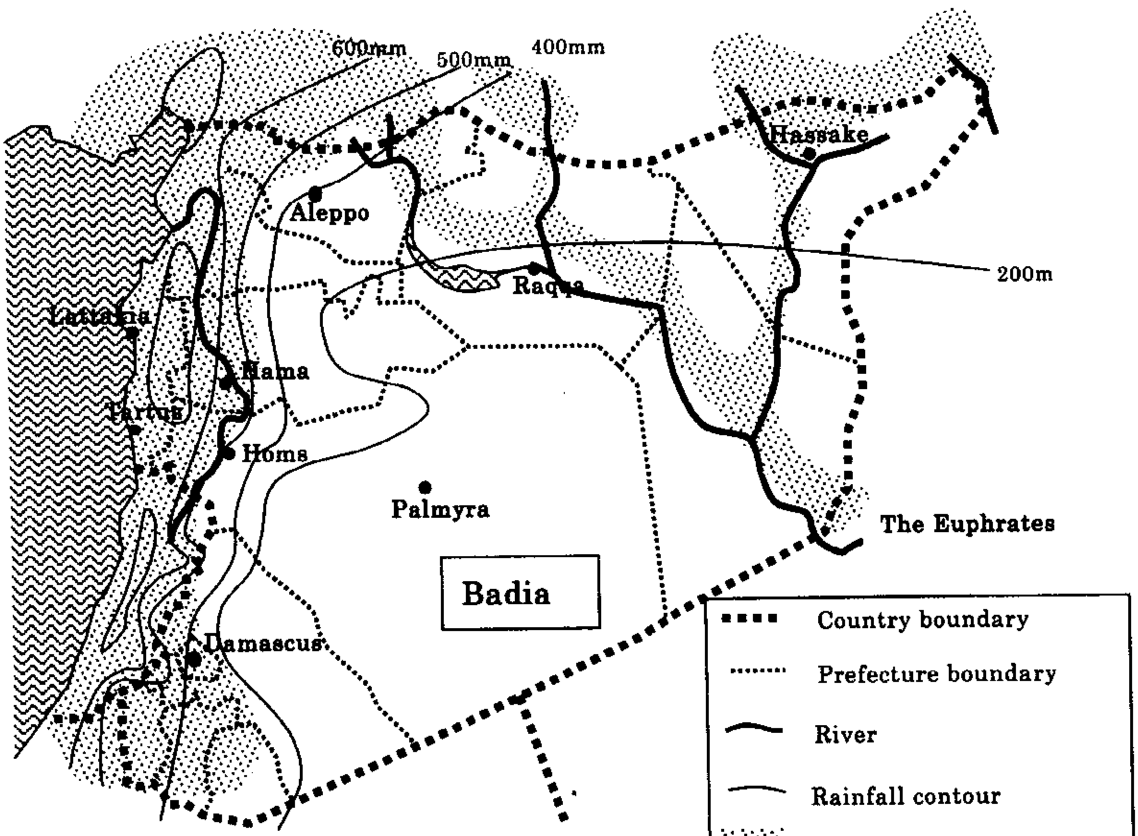
On the other hand, the exports of agricultural products have been increasing in the last few years; cotton wool and sheep as well as vegetables and fruits are exported.

From the past up to the present, the gulf area and Lebanon being a neighboring country provide large markets for the agricultural products of Syria. In the last three years, cotton wool accounted for 5 ～10% of the total export of Syria, and the largest customer is the textile industry of Italy, followed by Taiwan and Turkey.

2.3 Water situation of Syria

2.3.1 General water situation

Except the western coastal area, almost Syrian land belongs to the dryness climate, and about 3/4 of the country is the arid area, called Badia. The coastal area has a rainfall of 500-1,000mm and farming can be done fully, but rainfall becomes very low to the east of mountainous area. Area for rainfall of 500mm or more is the western side of the line of Aleppo-Hama-Homs-Damascus. East of this area except for northern part become Badia area. Since most of the rainfall of this area, which is less than 200mm, evaporates soon after it rains, it is difficult to utilize. The Euphrates River is indeed a big water source but the usage of the river water is strongly limited because it is an international river. At present the usage of the river is limited to Aleppo and the villages around the pipeline from the Euphrates to there.



(From "Syria-, the country and the market-": KagakuSinbun)

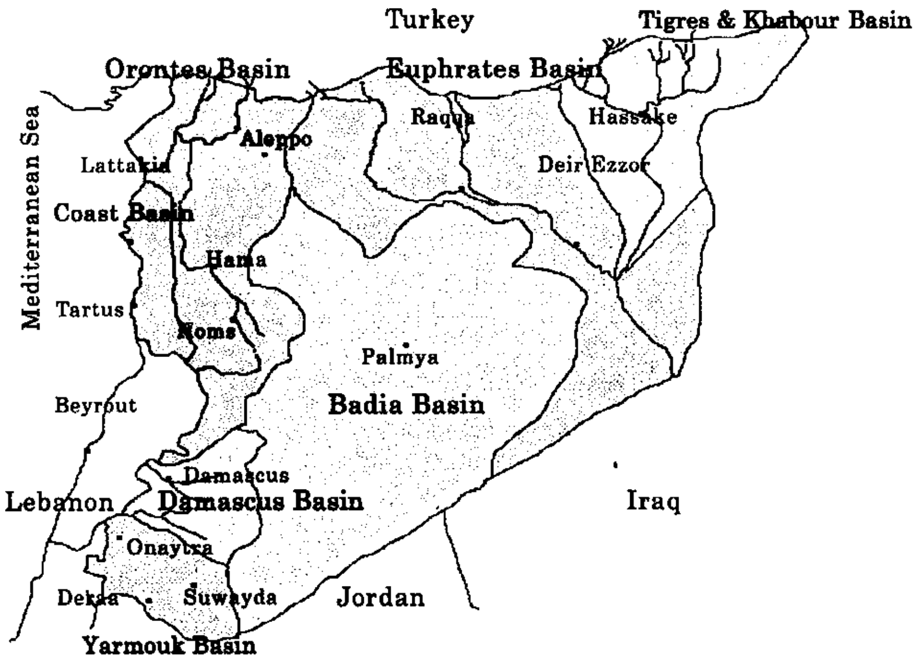
Fig.2.3-1 Water situation of Syria

2.3.2 Rainfall

The climate pattern of Syria belongs to that of Mediterranean, usually it rains from October to March next year and sometimes it snows in the high mountain area. The rainfall of this area is not stable and varies much according to the variation of the land resulting only 100mm in some places to 2,000mm in another places. The total amount of rain fall around the year whole the country is ~46 billion m³. The rainwater of the area of less than 100mm fall, which is 5.7% of the country, estimated to be 550 million m³, which is about 1% of the total rainwater. This amount seems large but it completely evaporates soon after it rains. The area of 100mm~200mm rainfall, 69.7% of the land, is estimated to be 25 billion m³ which is about 48.1% of the total rainwater. This also evaporates or flows out to the sea. Therefore, Syria is now facing how to control and utilize this water.

2.3.3 Surface water

The hydrologic survey in Syria starts from 1960 by the Ministry of Irrigation about the resource of dry and arid area, the history of underground water and new under ground water directly flown though Osaki layer. Based on this survey, the land of Syria is classified into seven parts as is described in Fig.2.3-2.



Source : Summary about the situation of Water Resource in Syria
(Eng. Barakot Hadid Deputy Minister the Ministry of Irrigation)

Fig.2.3-2 Area of river basin in Syria

There are 10 main rivers in Syria as is listed in Table 2.3-1. Most of the other rivers can only keep water for several days to several months if there is much rainfall. Most of these rivers locate near coastal area. In these areas, mountains are not high and close to the shore. Therefore, these rivers are short and rainwater flow instantly like a flash flow. So most water goes directly into the sea without utilizing.

Table 2.3-1 Major rivers in Syria

Rivers	Average flow m^3/sec	Annual flow Million m^3	Location of the Spring	End	Length/ km
Euphrates	995	31,400	Arminia hill		680
Khabour	50.7	1,600	Ras Alein	Euphrates	442
Tigris	586	18,700	Toroas mont	Arab gulf	1,718
Assi	25.8	813	Lbwa and Hermel	Mediterranean	485
Kaber Shamali	6.6	210	Al Akre mont	Mediterranean	96
Kaber Janoubi	7.96	251	Barshen South	Mediterranean	76
Al Sin	9.9	315	Al Sin spring	Mediterranean	6
Barada	4.9	315.4	Barada spring	Otaibe lake	81
Al Awaj	1.5	100	Harmon mont	Haijane lake	70
Yarmouk	6	440	Mzaired spring	Jordan river	60

Source : Summary about the situation of Water Resource in Syria
(Eng. Barakot Hadid Deputy Minister of the Ministry of Irrigation)

Since the surface water is very necessary for agricultural planning, the government of Syria pays much attention to minimize the loss of it. For this purpose, now 146 dams are constructed. From the figure, there is strong correlation between the population and water demand, and both increasing rapidly. The demand for water increases to be about 40 billion ton/year in 2025. Therefore, securing of the new water sources not only from the underground but also from the surface or some other ways is very important.

2.3.4 Underground water

Since surface water resource is not enough as described before, dependence on the underground water utilization is very high. The amount of current underground water usage is estimated ~10Bm^3/year, which is 60-70% of total possible value. For the area without surface water, which is most of the country, underground water is the only and most important water resource. Table 2.3-2 shows the most important wells in Syria.

Table 2.3-2 Lists the most important wells in Syria.

Name of Spring	Location	Ave. flow m^3/sec	Feeding layer
Ras al-cin	Euphrates basin	40(too low)	Eocen lime stone
Al-hosain	Coastal basin	6	Jurassic line stone
Al-feijeh	Damascus basin	8-13	Jurassic line stone
Barada	Damascus basin	3-3	Jurassic line stone

Source : Summary about the situation of Water Resource in Syria
(Eng. Barakot Hadid Deputy Minister of the Ministry of Irrigation)

2.3.5 Necessity of water resource in the future

(1) Estimation of water demand

The high birth rate and the increase of population cause the security of water for both domestic and industry to be most important subject in the future. Table 2.3-3 shows the water demand of domestic and industrial use, and Table 2.3-4 shows the demand for irrigation use.

Table 2.3-3 Demands for water for industrial and domestic uses (10^3m^3)

1992		2000		2025	
Domestic	Industrial	Domestic	Industrial	Domestic	Industrial
761,000	237,804	1,277,500	480,906	282,366	1,292,835

Source : Summary about the situation of Water Resource in Syria
(Eng. Barakot Hadid Deputy Minister of the Ministry of Irrigation)

Table 2.3-4 Water demands for irrigation (Unit: $M.m^3$)

1992	2000	2025
10,998	15,367	19,429

Source : Summary about the situation of Water Resource in Syria
(Eng. Barakot Hadid Deputy Minister of the Ministry of Irrigation)

(2) Way to solve the water demand increase

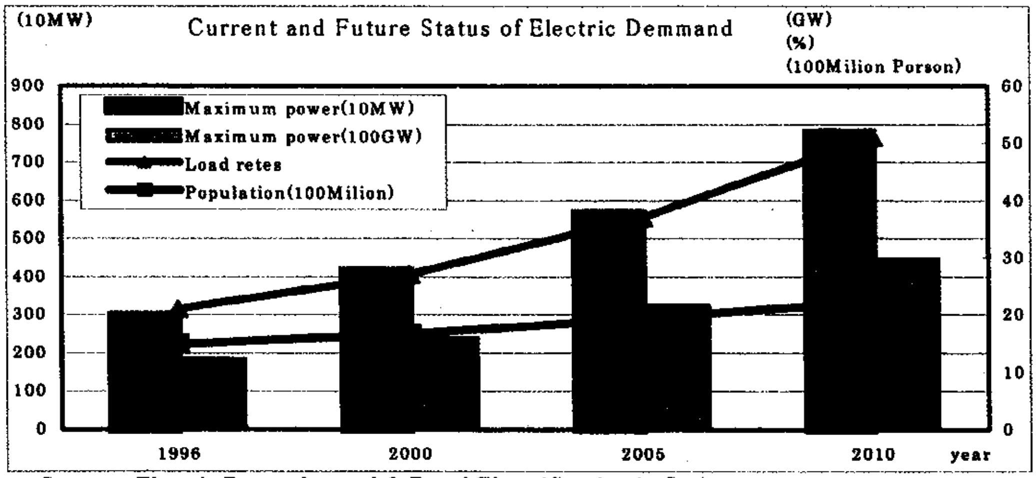
The utilization of wastewater from agricultural use is the most important subject for reducing the total water quantity for irrigation. For this purpose the long-range environment assessment should be done elaborately. Quality and quantity of agricultural wastewater depend on the area. Salinity of the water used for this purpose should be less than 1,000ppm, and desalinating method is also paid much attention. For now, quantity of recycled water from agricultural use is estimated to be 25% of the used quantity.

For dry or arid area such as Damascus basin, the water quantity used for irrigation is most important. Current way of irrigation accumulates saline on the surface of the ground. The dependence on the underground water of Damascus is very high due to the domestic use and livestock and planting as well. Excess use of underground water is inhibited but this sometimes causes another problem. Therefore, the rational way of use and recycling water is important. The water recycle in the field of agriculture begins in Europe, North America, Australia, and assessment of this impact has also begun. Moreover, the demonstration plant of water treatment relating water recycling is constructed and now on the way to start. Same plants are also under construction in Aleppo and Hama.

2.4 Electric utility and status of electrification

2.4.1 Conditions of electricity

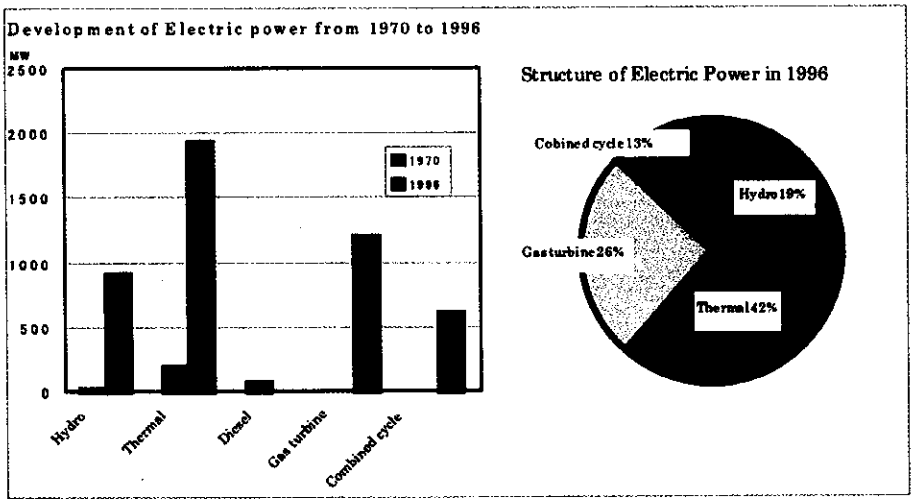
According to the presentations given by the Minister of Electricity and the Assistant Minister of Electricity in the workshop held in Aleppo University on September 22, 1997, the situation of electric power in Syria were found. The present condition and future forecast of power demand in Syria are shown in Fig.2.4-1. With the rapid increase in population, the maximum power peak will increase from the present 3 million kW to about 8 million kW in 2010. This is due to the modernization of cities and the improvements in living through expansion of electricity. The annual load factor will be improved from the present 20% to 50%.



Source : Electric Power demand & Rural Electrification in Syria
(Eng. Suhyan Allow : Assistant Minister of Electricity)

Fig.2.4-1 Present status and future forecast of power demand

This would require a large investment in electric power development and expansion of transportation facilities. Examination of the past progress of electric power development reveals the changes in power supply. About twenty years ago, the major sources of supply were thermal power plants in the suburbs of large cities, diesel plants and hydropower plants. In recent years, efficiencies have been improved significantly using latest technologies, such as combined cycle power generation, high temperature gas turbine, and new thermal power plants. Through the continued efforts to introduce new technologies, the stable supply of power will be ensured in future. To meet the transportation facilities with these supply capabilities, Syria is expanding 400kV transmission lines over the national land, and is striving to interconnect power systems with those of Egypt, Jordan, Iraq and Lebanon by 2000. Syria also has a plan to interconnect with the transmission networks of Europe after that. Thus Syria hopes to ensure stable supply of electricity through electric power interchange in future.

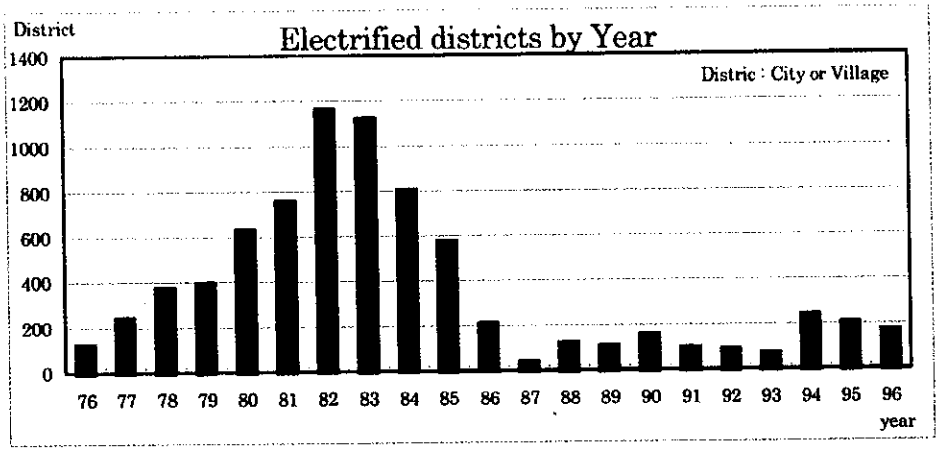


Source : Electric Power demand & Rural Electrification in Syria
(Eng. Suhyan Allow : Assistant Minister of Electricity)

Fig. 2.4-2 Transition of power source development from 1970 to 1996

2.4.2 Situation of electrification

Syria is a developing country, and has been exerting much effort to develop the infrastructure, such as expansion of power supply capability and road networks. Except cities, the electrification rates of rural villages that are scattered over wide areas are varied from place to place. The advancement of electrification over years is shown in Fig.2.4-3. In this diagram, the unit is an administrative section. Electrification was pursued positively up to the middle of 1980s. In the latter half of the 1980s and beyond, the numbers of electrified units hovered at low levels. This decline in the electrification efforts is attributed to the emergence of power development as an important issue. The government gave priority to the elimination of power shortage. Another reason is that for some areas electrification is completed.



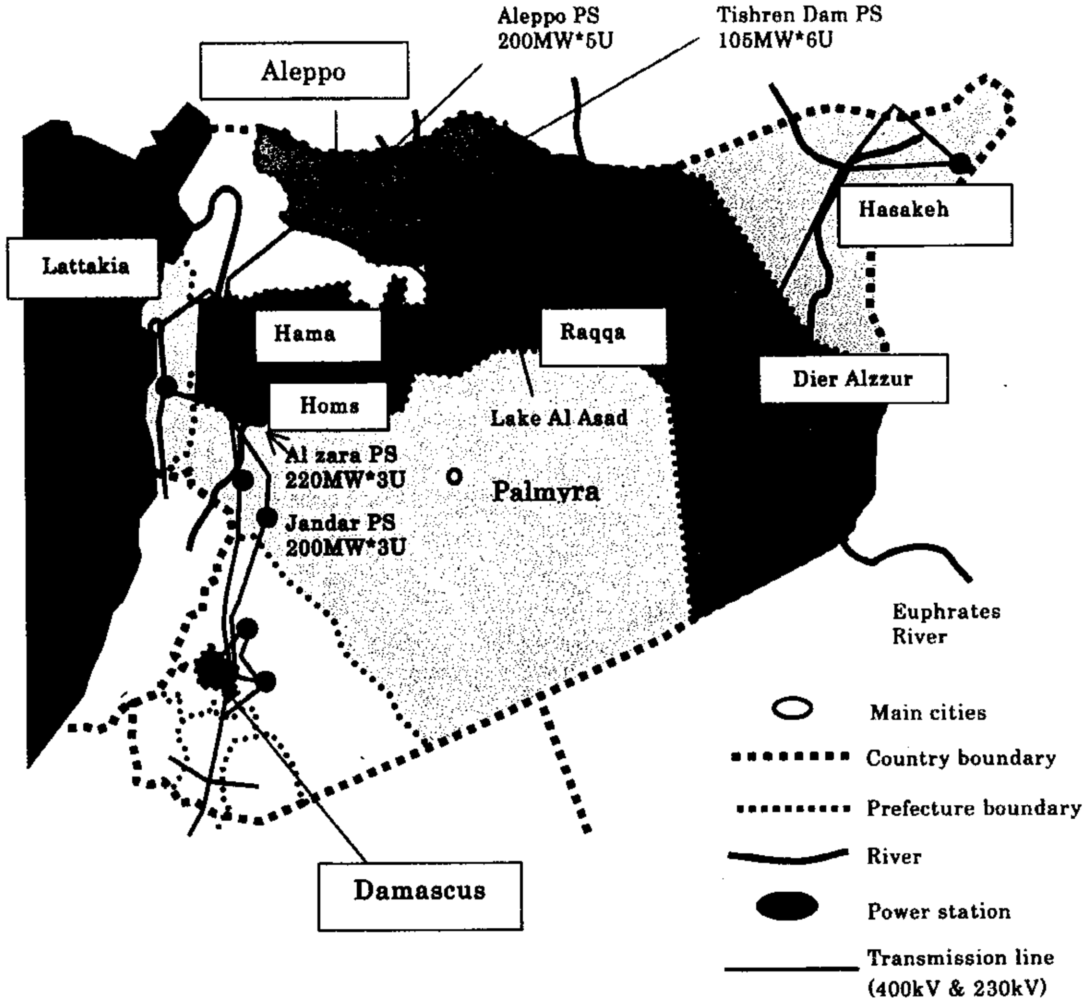
Source : Electric Power demand & Rural Electrification in Syria
(Eng. Suhyan Allow : Assistant Minister of Electricity)

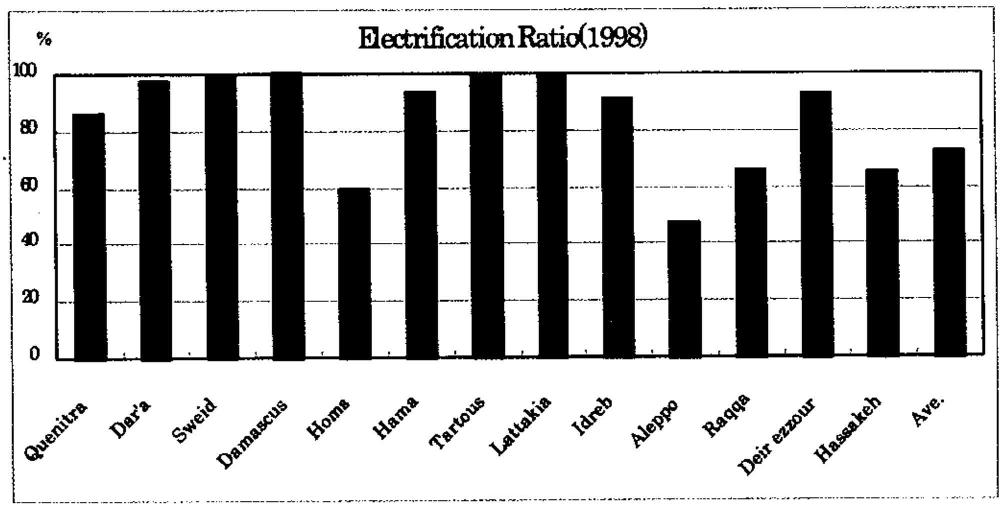
Fig.2.4-3 Transition of number of electrified unit

The state of electrification by area (unit: city or prefecture) is as shown in Fig.2.4-4. In the greater part of the areas, the rate of electrification has reached 100%. Of the remaining areas, the area of Aleppo has the lowest electrification rate.

On the other hand, to meet the rapidly growing demands for electricity, Syria has a keen interest in developing technologies for utilizing renewable energy sources. For example, because of the meteorological conditions of Syria, a long spell of fine weather lasts in summer. Solar energy is plenty. Around Hama, one may harness wind power that is very stable even when judged by the global standard. The government of Syria is promoting demonstrative research in harnessing these energy sources, including the use of biomass energy in agricultural areas.

In this area, we are promoting a plan of enhancing people's livelihood through the use of PV system.





Source : Interior data of the Ministry of Electricity

Fig.2.4-4 Electrification rate by prefecture and transmission route

Chapter 3

Feature of Un-electrified Village in Syria and Outline of Project Site Village

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On Aleppo area, which include this project site village, historical background and social feature is mentioned and general feature of mountainous area and plane area, which located project site, is indicated as well. At the each area, the objective villages that are installed PV system are classified. In addition, the feature and outline of these villages are mentioned in this chapter.

3.1 Feature of un-electrified village in Syria

3.1.1 Historical outline around Aleppo

Four villages, which are installed PV systems, are located in Aleppo prefecture, which occupies the northwest part of Syria. Prefecture capital city Aleppo is 2 million or less populations (being about 4 million in Aleppo prefecture). Aleppo is a big city, which equals Damascus and it is the center of the commerce and industry in the country and located on abundant agricultural zone around.

In her history, Aleppo is supposed to have existed already under the government of the Sumer era around 2900 B.C. and it is one of the oldest cities in the world as existing city still now. Aleppo was belonged Islamic territory since 7^{th} century under the Islamic dynasties such as Omayyad(AD661-), Abbas(AD749-), Tourun(AD877-936) and continued to Ottoman(AD1516～1918) dynasties. Aleppo was only once it became the capital of dynasty in the Hamdan in AD944～1003.

The character of the city is basically as the economic city lather than the political city. The cause why it continued long in this way as the economic city must be considered from both sides of the natural and the institutional circumstances, which surrounds Aleppo.

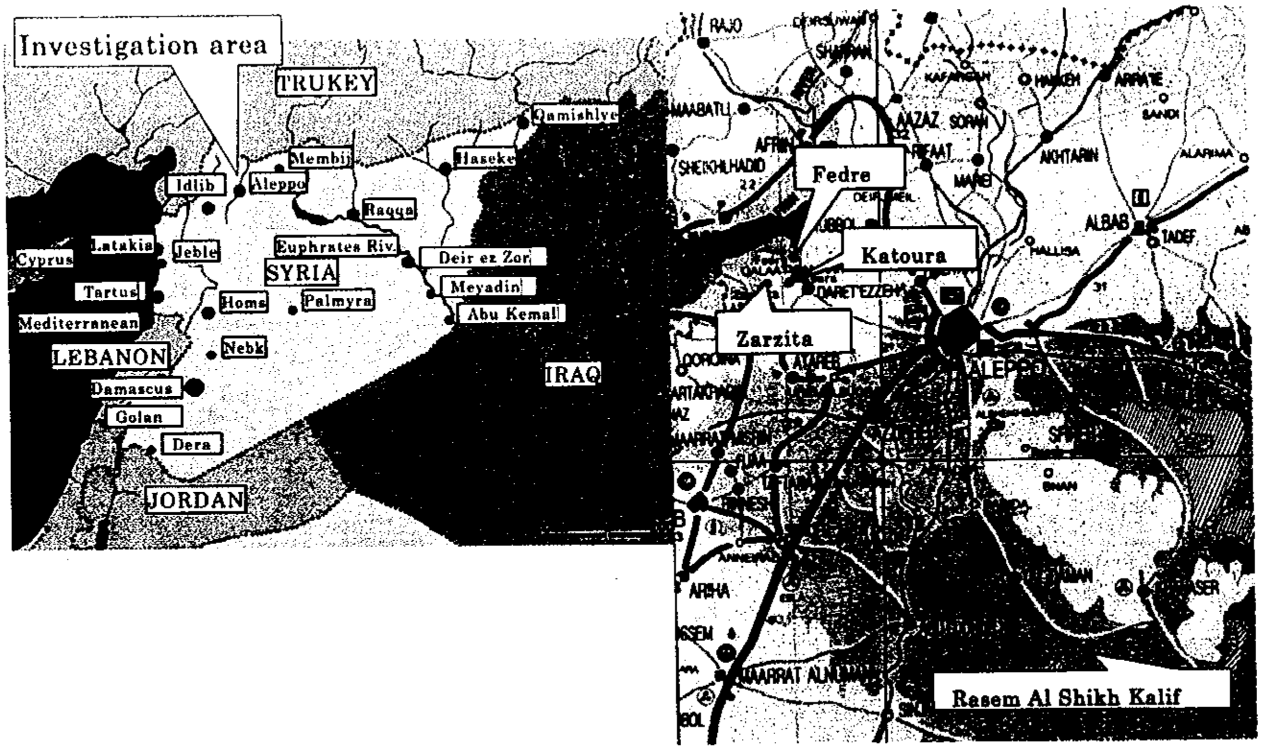


Fig.3.1-1 Map around Aleppo

(1) Natural circumstance :

Aleppo belongs to Mediterranean Sea climate zone where is damply in the winter dry in the summer, but there is a mountains between the coastal area and the city of the western part that make the area as the step climate. There is a mountain zone in the west of Aleppo, where annual rainfall exceeds 400mm and as for the southeastern side, the boundary line of annual rainfall below about 250mm is near. In the area, which exceeds 400mm, the pomiculture of the olive, the grape and so on becomes possible only with rainfall water.

In the area from the southwest in Aleppo to the northeast, where the amount of rainfall falls below 400mm, the growing of a wheat kind becomes of primary concern and the area with 300-400mm amount of rainfall is the granary belt zone of the cereal growing. An inland part in this belt zone, the amount of rainfall about 200mm, needs some artificial irrigation to the cereal growing or becomes nomadism centered on the sheep with by gamble agriculture which expected sometimes much falling rain by chance.

The difference of the production form appeared in both sides in Aleppo. Moreover, in the area from the Mediterranean Sea to Iraq through inland of Syria, it is the production center of the cereal, the olives and the grapes. Also, in the step and the

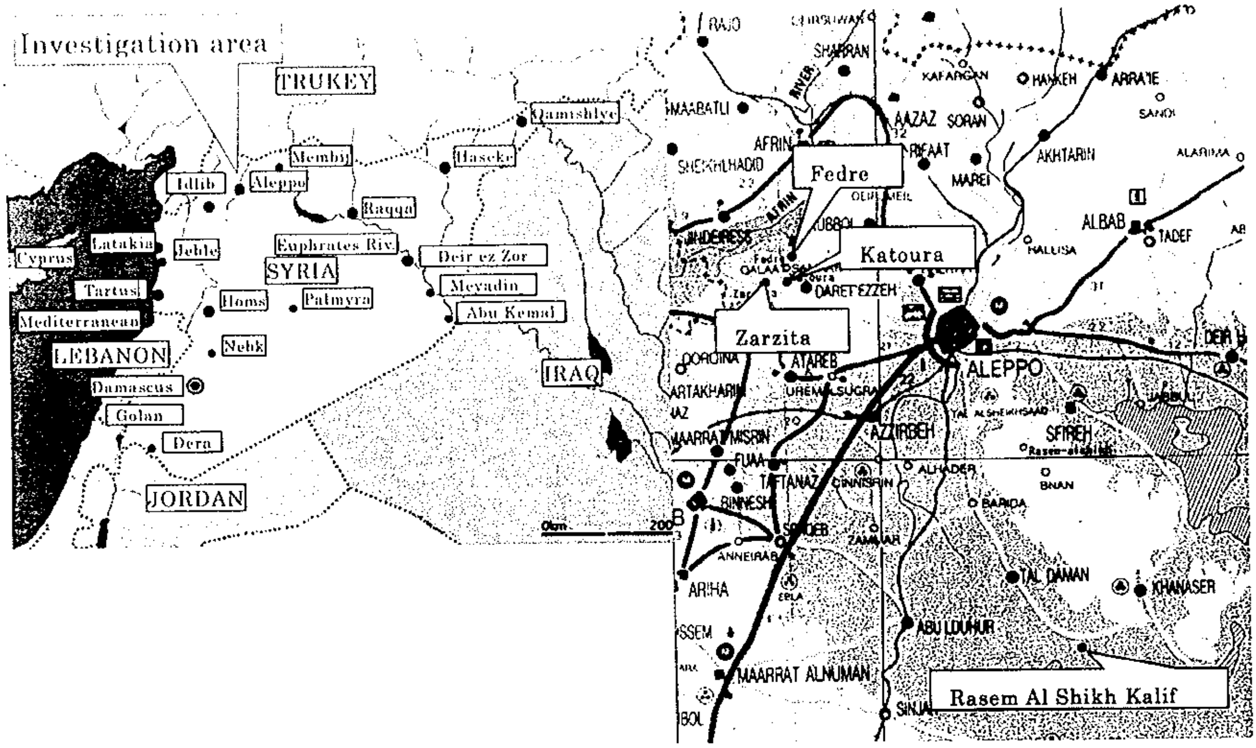


Fig.3.1-1 Map around Aleppo

(1) Natural circumstance :

Aleppo belongs to Mediterranean Sea climate zone where is damply in the winter dry in the summer, but there is a mountains between the coastal area and the city of the western part that make the area as the step climate. There is a mountain zone in the west of Aleppo, where annual rainfall exceeds 400mm and as for the southeastern side, the boundary line of annual rainfall below about 250mm is near. In the area, which exceeds 400mm, the pomiculture of the olive, the grape and so on becomes possible only with rainfall water.

In the area from the southwest in Aleppo to the northeast, where the amount of rainfall falls below 400mm, the growing of a wheat kind becomes of primary concern and the area with 300-400mm amount of rainfall is the granary belt zone of the cereal growing. An inland part in this belt zone, the amount of rainfall about 200mm, needs some artificial irrigation to the cereal growing or becomes nomadism centered on the sheep with by gamble agriculture which expected sometimes much falling rain by chance.

The difference of the production form appeared in both sides in Aleppo. Moreover, in the area from the Mediterranean Sea to Iraq through inland of Syria, it is the production center of the cereal, the olives and the grapes. Also, in the step and the desert area produces the oils and fats of the flesh and meat, those different production forms exerted an influence on each eating habit, too. This difference of production and eating habit were the motive power of Aleppo to bring the commerce center of the area.

In addition to the difference in such an area, Aleppo is situated on the nod in east and west of the geographical meaning, was prosperous as the central point of the commerce with the international trading. The triangle, which Aleppo forms with Baghdad and Cairo, was the nucleus of the international commerce, which links Europe, northern Africa and southern and eastern Asia from the era of the Abbas dynasty.

(2) Institutional circumstances :

For the city to be prosperous economically, the institutional circumstances which can distribute just wealth independently must be ready. At this point, the order with the economic relation which al-Islam provides played an important role. In the comprehensive rule by al-Islam which provides the comprehensive rule of the social relation, such as:

The contract is concluded by an agreement of the will of the concerned parties.

The debt should be noted at the paper.

There must not be a chicanery in products to handle and so on.

The rules with the basic economics relation that includes an ethics, too, were established

Also, it is possible to say that the systems were well arranged to be the center of the international commerce, too. The building, which is called "Khan", was the office and the hotel of the merchants who came from the other places. It has only one big gate as the entrance to the building surrounding a big court and was partitioned by the small room. The safety of the merchants inside the "Khan" was kept with a key hung from inside in night. The Islamic law is worthy about that concluded an international relation rule (the rule of judging relation between the Islam believer and the religion party except it) already at the time of the 9th century. Aleppo shows that it is steadily rooted until the present that it coexists while the different religion party respects a mutual belief each other. At least, in case of Aleppo, seems to have been fairly matched with such institutional circumstances and to have built up long prosperity history.

3.1.2 General feature of villages in the plain area

In the plain area, some villages carried out systematic irrigation and some villages depend only on the rainfall for their agriculture. There is a big difference in the yield for the unit tillage in the irrigated area and non-irrigated area and thus causes the big difference on their income.

In the eastern part of Aleppo, irrigation cannel from the Euphrates River is serviced and the wide cultivated land is spreading. On the other hand, in the southern part of Aleppo, the area where is like Jabal al Hoss is irrigated by the underground water. Outside of that area, only depend on the natural rainfall and small wells for watering. The growing of a cotton, an olive, an almond, vegetables and so on are cultivated in the area which an irrigation facilities are provided and the large scale pumping can work. The machines such as tractors, sprinklers, and combines are introduced in the wide cultivated land. One of un-electrified villages in that plain, the village has only six houses but owns the olive trees (several ha) and 200 sheep, even has one tractor for the tillage and they were pumping up water by diesel engine for irrigation. On the other hand, the development area and around of it, villages depend on small-scale agriculture and the pasturage (the nomads) mainly sheep and goat. Because, cow breeding needs a lot of drinking water and feed, so that, breeding is difficult in the small water quantity area.

Rasem Al Shikh that is the original candidate village to introduce desalination system and located in the southern part of the plain area is un-electrified village, but they have a large cultivated area irrigated by diesel engine pump. On the agricultural work such as seeding and harvesting, labor of villagers are not so necessary because of rental machine with operators. Regarding electrification by PV system, neighbor village (about 1km from Rasem Al Shikh) electrified by the grid line, in addition, within a few years, Rasem Al Shikh will be connected to the grid based on the plan of the Aleppo Electric Authority and also the fresh water was got by digging the new well. Therefore, the introduction of PV system was stopped.

In any mountainous area and plain area villages have more than 80-100 houses are electrified by the grid extension in advance but villages with tens of houses are often left. The distribution line didn't extend more than 10 years even after electrified 2-3km ahead, the request of electrification is very strong in these area In some visited homes, though there is no electricity, have a refrigerator and a washing machine and are waiting for the electricity to come.

3.1.3 General feature of mountainous village

In the mountainous area around Aleppo, there are two types. One is completed plantation of fruit tree such as olive and so on. The other is no trees such as olive etc and exposed the surface of the mountain. The occupation of the area therefore, one area is doing mainly the pomiculture (an olive is primary concern, including an almond and a pistachio). The other is doing a small-scale pasturage along with growing cereal and vegetables on a small scale. Economically, the area where is possible to do pomiculture is regarded as being abundant more than the other area.

The olive requires water only the time of the sapling (3-4years). If an area with the amount of rainfall in 200-300mm/year, it says that olives can growth only by the rainfall after their sapling, that the olive is strong in the dryness. The village in the mountainous in northern part of Aleppo, which the study team had visited, possesses 300-500 olives per house. Some villages have their own olive oil press factory and the manufacture factory of the olive soap, which is famous as the special product in Aleppo. Even if it is an un-electrified village, some households possess TV and use them with car battery as a power source and for charging, the tractor engine is used. Also, in the un-electrified village, there was a house which was filled with a refrigerator, a washing machine, color TV and other electric appliances brought as trousseau in the new marriage, too.

As for the house, a square type is popular and built by piled cutting stones and the inside is completed with the mortar. The main room is about 5m x 10m and height is about 3m, high ceiling. A terrace or a rooftop is prepared as the place for the processing work of the farm products.

For the cooking, butane gas is mainly used, for the heating, gas oil is used and a kerosene lamp or a partly, butane gas lamp are used for the lighting. The branch is used from the olive trees cut by tree arrangements as the firewood and dung of livestock dries up and used as fuel.

Generally, mountainous village has smaller cultivated area and deeper underground water level than the plain area. Therefore, the mountainous village tends that harvesting volume per unit area is less and income is lower than the plain area. Moreover, density of houses in village is comparatively higher than the plain area because of limited village area.

3.2 Outline and feature of the objective village

3.2.1 Feature for the area to be electrified

According to Table 2.4-1 in Chapter2, on the progress of village electrification in Syria in 5 years from 1993 to 1998, the number of the electrified village is increased 1,095 that are from 7,285 to 8,380. Total number of un-electrified village is decreased from 7,470 to 4,107 including total number of village decreasing by combined together. This means that about 200 of villages are electrified per year. However, under this condition, in Aleppo prefecture, about 50% of villages is still un-electrified.

At the workshop held in September 1997, regarding the electrification plan, the Assistant Minister of Electricity pressed as follows.

1) At first, 1,400 of villages, which have more than 100 houses, are made effort to electrify by the grid extension.
2) On the other hand, regarding the villages, which have less than 100 houses, the introduction of decentralized electrification such as PV system has advantage economically than the grid extension.

Therefore, on the villages, which have less than 100 houses, the order of priority is low under the present electrification plan by the grid extension.

By the interview survey from the Aleppo Electric Authority, the villages which has more than 100 houses are prior to electrify by the grid line according to the plan of the Authority. The objective villages of this project have 15 to 40 of the number of houses, so that, these villages has low priority to electrify by the grid line.

Based on the survey of the Aleppo Electric Authority, in Aleppo prefecture, about 1,500 of villages are not electrified at May 1998. About 1,100 of villages are small-scale villages, which has less than 100 houses and are the objective villages by the decentralized electrification such as PV system. In Homs, Hassakeh and Raqqa, many un-electrified villages are there and their life style is close as the villages in Aleppo. Through this project, PV system is introduced around Aleppo and the effect of human life improvement of villages is studied. The outcome of this project has a significant result for promoting rural village electrification by the decentralized electrification such as PV system.

3.2.2 Feature for the area to be supplied water

Almost all of villages in Syria depended on the rainfall or pumping water from well for the water of human life and agriculture. But, a part of the plain area, the big scale irrigation facility was installed by the effort of the government of Syria and this is big contribution for the improvement of the agricultural production.

On the other hand, at the area, which has no irrigation facility, agriculture depends on rainfall and water for human life also depends on rainfall and buying water. There are underground water pumping to use for agriculture and human life. On some area, underground water is salty and this water is not available to use for human life.

The underground water pumping using PV system is almost completed technology. If underground water is a suitable depth, the water pumping by PV system has high possibility economically and technically. To verify the water pumping from underground in mountainous area, Zarzita which houses is gathered and water supply is easy comparatively was selected. On Zarzita, in rainy season, rainfall is stored in the underground tank and in dry season, water is bought from outside. Therefore, self-sustenance of water in dry season is expected significantly.

On the other hand, desalination technology of salty water, the investment cost is fluctuated by the quality of law water and desalinated water quantity. Under the condition that is a reasonable number of houses and a quality of underground water such as total dissolved solution (TDS) etc, Kalif was selected by the result of survey from several villages. On Kalif, in dry season, water for human life depended on the buying water because of salty underground water. Hence, if self-sustenance of fresh water is possible, the villagers gain big profit. Because, water is not necessary to buy or it can be reduced.

PV water pumping expands the possibility of water supply to the villages, which has no way of self-sustenance without regard to the mountainous and plain area. On the other hand, desalination system is useful tool to keep human life water in the village of plain area that has only salty water.

Especially, Kalif is contact Jabal Al Hoss area where the government of Syria has been making effort to develop and the water supply for Jabal Al Hoss area is a big subject. Therefore, if the PV water pumping and desalination technology is able to verify, the development of water supply system to the dry area has a significant step and water system contribute to improve villager's human life.

3.2.3 Feature from socio-economic aspect

At the viewpoint of village socio-economic aspect, agriculture (including stock farming and pomiculture) is the method of life in many villages in Syria and might be divided roughly as follows.

1) Village in the plain area that does cultivated agriculture (grain, cotton wool, vegetable etc.)
2) Village in the mountainous area that does fruit plantation (olive, orange, apple, almond, pistachio etc.)
3) Village in the plain area that does stock farming including nomadic life.
4) Village everything mixture together

In the village, which does cultivated agriculture by irrigation and the village, which does fruit plantation in mountainous area, these has an economical margin comparatively. But, at un-irrigable area, villages that do cultivated agriculture, small-scale fruit plantation and small-scale stock farming has less economical margin generally.

The objective villages of this project is separated two types which is mentioned as follows and these four villages seems to be a middle or slightly lower position economically among the Syrian villages.

1) Zarzita, Fedre, Katoura

These three villages are located mountainous and un-irrigable area and cultivated agriculture, stock farming and small-scale fruit plantation is mixture together.

2) Kalif

The village is located in the plain and mainly small-scale stock farming including nomadic life.

In these villages, before installation of PV system, some families already bought TV and used by automobile battery. These batteries are charged by tractor engine or bring to the charging shop where is located in the electrified town. Torch lamp and radio cassettes powered by dry battery are possessed by almost all of families. For lighting, LPG and Kerosene lamp is used. This power for lighting, TV and radio cassette is supplied by PV system, and then improvement of villager's benefit will be expected.

Moreover, in these villages, if the family that has an economical margin is able to buy not only lighting and TV but also the other products such as washing machine, refrigerator and fan etc. Some of these families are required power supply to use these products. Zarzita and Katoura, some families are already possessed washing machine and want to use quickly after receiving power.

On the other hand, in Kalif, almost families still do nomadic life. In dry season, they leave village, so this village life is different as stable style.

Through this study, among the objective villages, the power consumption of each different PV system and system management including fees collection etc are surveyed and clarified these influence by the difference of economical level and main agricultural style. The results of this study are very important to make a future village electrification plan using PV system.

3.3 Outline of the objective four villages

3.3.1 Zarzita

Zarzita locates on a mountainous area where consists of the lime stone rock, about 35km of the northwest from Aleppo city and the number of households is 40 and some of them are built recently, about 400 people are living in.

There are an elementary school and a mosque in the village and teachers live in the village. The average number of people of the family is about 10, four by children (equal to or less than 12 years old), number of person over 60 years old is 0.5 in average and about one is living out of the village. (For the work or the school).

The main occupation of families in the village is agriculture and stock farming but there are many persons who take the job that brings a salary or a wage income such as policeman, teacher, clerk and staff of public office.

As for agriculture, main products are cereal such as wheat, barley and oat, fruiter such as fig and olive, breeding of cow, sheep and chicken. Their cultivating land is about 2 to 30ha per household but yield of the cropper mainly depends on the quality of the land and the quantity of manure and water. The yield of wheat is about from 500 to 1,000kg/ha, it is only about 1/4-1/2 of the Syrian average (Average amount of the whole Syrian is 2.5 tons of wheat/ha, 1.1 tons of barley/ha).

Some households have tractors for farming and transportation of the products, purchased water, feed and the manure, sometimes are used as a traffic means of villager to towns and markets.

There are ruins that are regarded as from Roman era in the village and some of them are using a part of their dwelling, livestock hangars and warehouses and so on. Most of traditional houses are constructed by putting together stone to make a wall and put on a flat roof that collects rainwater into a well (a water tank) in the rainy season. Some of old houses were built more than 100 years ago by traditional way but houses, which are built recently, are often using concrete blocks. There are 2 to 5 rooms in a house and a floor is smoothly completed with concrete.

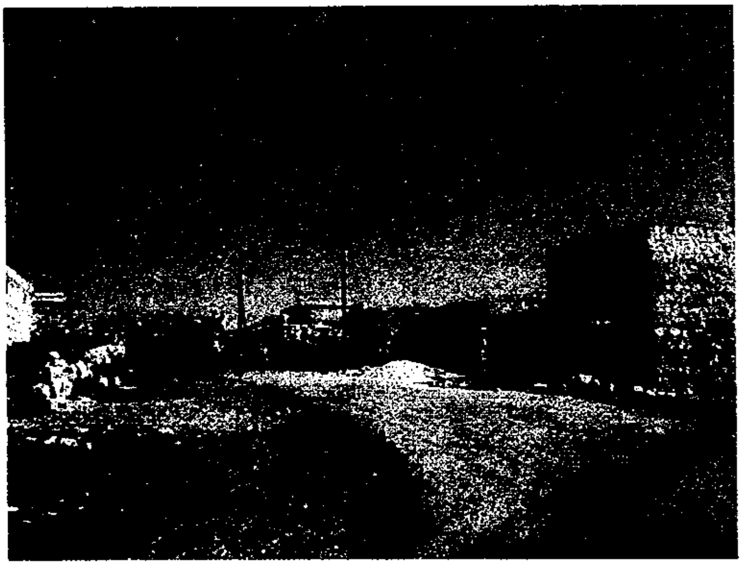


Fig.3.3-1 Appearance of Zarzita

Fig.3.3-2 Candidate area to build PV array in Zarzita

As for the plan of electrification had been made more than 20 years ago, but hardly seems to be implemented in near future. Villagers use kerosene lamps as the lighting and recently butane gas lamps are introduced. For the kerosene lamp, it is not bright enough and for gas lamp, problem is safety and noise.

TV is already introduced in several households and they are used with automobile batteries but time and expense are necessary to charge them either bringing them to electrified town or by a tractor engine. Also, there are households who have a refrigerator or a washing machine, and those villagers strongly expect to receive electricity.

3.3.2 Fedre

Fedre is about 2km from Zarzita to north by crossing one valley. There was a one more village beyond Fedre several years ago, but it abandoned already. Fedre is expected to revive power of PV system. The number of households is 13 (being 15 in the survey in 1994), the number of the villagers is about 80, and average number of people of one family is about six. New school was built recently.

Road is paved from Aleppo to Zarzita, but from Zarzita to Fedre road is not paved yet and sometimes collapses when strong rain falls. Villagers use a tractor as transportation among those village and towns. Recently, motorcycle is used to commute the town. The main occupation of village is agriculture and the stock farming and especially, income from stock farming occupied big portion.

Fig.3.3-3 Appearance of Fedre

Ruins are left in the village like Zarzita and are using a part for dwellings and livestock hangars, too. Some of houses in the village with a characteristic cone type roof in piling stone had built by one of villagers in the village by themselves.

The number of rooms to use is 2 to 3 in a house. This village locates the edge of the area that the electrification by the grid extension was hardly expectable in short terms, but some of households have purchased TV expecting the PV electrification. Gas lamps and kerosene lamps are using for lighting.

Rainfall is collecting into a water tank in the rainy season, but in the dry season relied on water to buy or to carry it from far and down well. The expectation for water supply is also strong.

3.3.3 Katoura

Katoura is on a way to Zarzita blanched from the road leads from Aleppo to the St. Simeon Castle, which is known as a famous monument. The village spreads on both sides of the road from plain to hilltops. There are 25 households, a mosque and a school as well. About 200 of habitants are in this village and also there are some ruins in this village too, such as a cave, a carved stonewall and pillars.

The productivity of the agriculture is estimated to be higher comparatively than Zarzita and Fedre as the land quality is good. There are large poultry farms nearby and buses are connected with the village and towns the forwarding of agriculture and a stock-raising article to market are easy. There is a limestone quarry near the village and the dug out limestone is transported to the processing factory or crushed there to suitable size to build house.

Fig.3.3-4 Appearance of Katoura

The dwelling has a flat roof of concrete, a wall by piling cut stone and many houses have a terrace to the southern side.

A grid line is passing just nearby the village and a neighboring village (town) is already electrified. The villagers expect to have electricity and some of houses are already possessed TV and radio cassette using automobile battery. Gas lamps and kerosene lamps are using for lighting. A telephone line is constructed recently and a telephone is installed in the some houses of village.

Rainfall is collected and used but in the dry season it need to buy water from outside. It is rather convenient location compared with Zarzita or Fedre in purchasing water. It may be cheaper transportation cost. There is a big poultry farm nearby the village where it pumps up water from a well by diesel generator.

3.3.4 Rasem Al Shikh Kalif

Kalif is located about 50km of the southeast of Aleppo and next to Jabal Al Hoss area across the road. The number of households is 25 and the number of the villagers is about 170, there are a mosque and a school in the village. As for the circumference, in the northern part hills of Jabal Al Hoss, in the southern part and the eastern part, there are salt lakes.

The village is in a shallow basin therefore, underground water is containing salinity and the soil quality is poor too, the productivity of agriculture is supposed to be low. In the rainy season, a shallow lake sometimes spreads just near the village.

As main occupation in this village, only one household does agriculture, and the others are difficult to depend only on agriculture. They depend on wage income from outside of the village and/or they breed sheep (keeping their own sheep or sometimes undertaking breeding other person's). There is a household to pump up water using the diesel engine and growing cotton. The dwelling is built with a thick wall of clay and covers a roof with wood or a plant like reed but recently, the dwelling uses a concrete block, and there are 1 to 3 rooms to use in a house. The dwelling is enclosed by an earth wall of about 1m heights, and encloses a livestock into it.

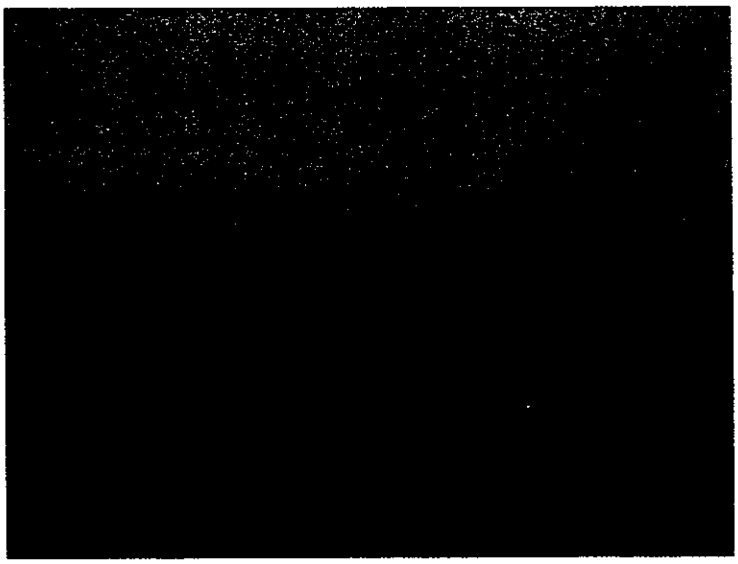


Fig.3.3-5 Appearance of Rasem Al Shikh Kalif

A grid line is passing just nearby the village and the grid extension seems to be easy, but a number of households are small and power consumption is supposed to be little. Therefore, the grid extension is hardly expectable in near future.

Kerosene lamps are mainly used for the lighting. There are some households watching TV by using automobile batteries and charging them with diesel generator.

They almost depend on purchased water because it is difficult to collect rainfall on their roof and doesn't suit the well water for drinking.

3.3.5 Summary of outline of objective four villages which introduced PV system

The outline comparison of objective four villages, which introduced PV system are shown in Table 3.3-1. Historical and geographical outline of Aleppo, general feature of mountainous and plain area in Aleppo and outline and features of objective villages, which introduced PV system were mentioned in this chapter. The objective villages were classified for studying the introduction of PV system into Syria.

According to the implementation of this study, PV systems were installed and utilized. As a result, the influence for rural area development and the acceptability of the villagers by each PV systems are surveyed and the results of this study are expected to apply the introduction plan of PV system for future.

Table 3.3-1 Comparison of objective four villages

(Exchange rate at 1998 : 1US$ = 46SP)

	Zarzita	Fedre	Katoura	Kalif
Location	30km Northwest from Aleppo	Same as Zarzita	Same as Zarzita	50km Southeast from Aleppo
Topography	Mountainous	Mountainous	Plain to Hilly	Plain
Number of houses 1997	40	13	25	25
Number of households	40 (increasing)	13 (decreasing)	25 (increasing)	25 (increasing)
Average number of person(1997)	Man 4.8 Woman 4.6 Total 9.4	Man 2.8 Woman 3.4 Total 6.2	Man 4.6 Woman 3.6 Total 8.2	Man 3.3 Woman 3.4 Total 6.7
Total number	376	81	205	168
Less than 12	39%	48%	36%	45%
More than 60	4%	7%	5%	6%
Main occupation	Agriculture Wage working	Agriculture Wage working	Agriculture Wage working	Wage working Agriculture
Main cropper	Wheat, Barley Olive	Wheat, Barley Olive	Wheat, Barley (Olive)	Wheat, Barley
Main Livestock	Cow, Sheep/Goat Chicken	Cow, Sheep/Goat Chicken	Cow, Sheep/Goat Chicken	Sheep/Goat, Chicken
Average number	Cow 2.8 Sheep/Goat 20	Cow 5.3 Sheep/Goat 32	Cow 3.5 Sheep/Goat 40	Cow 0 Sheep/Goat 20
Water	Rainwater, Well Purchasing	Rainwater, Well Purchasing	Rainwater, Well Purchasing	Well(saline) Purchasing
Illumination	Kerosene lamp Gas lamp	Kerosene lamp Gas lamp	Kerosene lamp Gas lamp	Kerosene lamp
Dwelling wall roof	Stone Plane(concrete	Stone Plane/Coned	Stone Plane(concrete)	Clay Plane(wood)
No. of room	2 to 5	2 to 3	2 to 4	1 to 3
Road	Paved	Unpaved	Paved	Unpaved
Nearest town	Dartazze (7km)	Dartazze (9km)	Dartazze (5km)	Abu AlZuhur (5km)
Average income	77,000SP/year	41,500SP/year	72,000SP/year	68,500SP/year
Per adult *	14,400SP/year	14,900SP/year	14,900SP/year	20,900SP/year
Expense for food	61%	53%	57%	---
For fuel	6.1%	6.8%	9.0%	4.4%
For lighting	2.3%	3.6%	4.3%	1.5%

Chapter 4

Village Electrification Powered by PV System

Chapter 4 Village Electrification Powered by PV System

In general, PV systems are classified into stand-alone type using batteries and grid-connection type connected to distribution lines. For this project, not grid-connection systems but stand-alone systems are appropriatc because electrification of rural areas is the main object.

Furthermore, the stand-alone systems are divided into centralized PV systems, which have centralized PV arrays and supply electricity to each house through distribution lines, and individual systems, which are installed independently in each house and supply electricity only to the house.

This chapter gives details of the selection of villages and the design, installation, operation, and maintenance of a centralized, individual system. In addition, technological improvements to the PV system in Syria and cooperation with UNDP are described.

4.1 Selection of village and outline of each facility

In Aleppo prefecture which the electrification rate is lower than other prefectures in Syria, the objective villages were selected to meet the following condition.

a. These PV systems are the first experimental facilities. To master the technology of operation management and maintenance, the counterparts need to commute to the site village frequently. The subject villages were selected based on the accessibility and the distance from the counterpart office.

b. Village electrification by grid line is executed from large population village or closer distance village to grid. Based on those conditions, the village which is not the target for grid extension by PEDEEE within 10 to 15 years was considered.

As a result, four villages that are not far from the existing grid line but are difficult to nominate for grid extension by the Electric Authority at present were selected. The features of these villages are shown in Table 4.1-1.

Table 4.1-1 Outline of selected villages

Zarzita	About 40 houses are built together in a mountainous area. The public area is open to the southern slope area. Therefore, a centralized PV system that concentrates PV arrays in one place is installed and power is distributed by a grid line.
Fedre	The village is located in a mountainous area like that of Zarzita and the houses are spread apart. Inside the village there are no open areas so individual small-scale PV systems are installed.
Katoura	The houses in the village are located on both sides of the road to Zarzita. Thus, individual small-scale PV systems are installed as in the case of Fedre.
Kalif	The village is located on a plain. Inside the village, there are groups of two or three houses and the groups are located apart from each other. So, individual medium-scale PV systems are installed and shared by houses in each group.

Outline of each facilities are shown below.

Zarzita

Type of system	Quantity	Outline of main equipment
Centralized system	For 40 houses	PV array 35kW Inverter 40kVA Battery 336kWh Distribution facility In-house facility Pre-fabricated house etc

Fedre

Type of system	No. of system	Outline of one system
Individual DC system (DC200W)	15	PV array 200W Controller 300W Battery 2,400Wh(1 x 12V-200Ah) In-house facility etc

Katoura

Type of system	No. of system	Outline of one system
Individual DC system (DC300W)	24	PV array 300W Controller 300W Battery 2,400Wh(1 x 12V-200Ah) In-house Facility etc

Kalif

Type of system	No. of system	Outline of one system
Individual AC system (AC500W)	17	PV array 530W Controller 500W Inverter 500W Battery 7,200Wh(6 x 12V-100Ah) In-house facility etc

4.2 PV system design

4.2.1 Basic action of PV system

Basically, the design of a PV system should result in a balance between the power generated from PV modules and consumption. The depth of discharge for battery should not be more than 70% of its capacity. Available capacity should be sufficient for about two days of consumption. A block diagram of the system is shown in Fig.4.2-1.

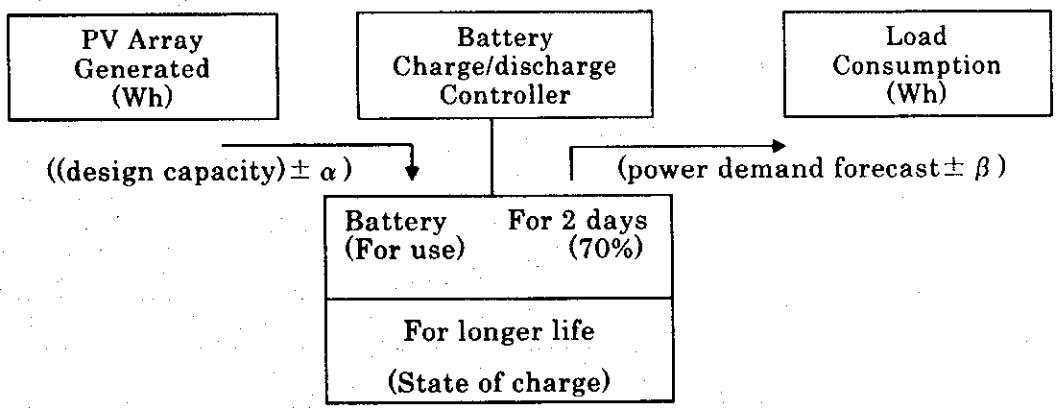


Fig.4.2-1 Block diagram of power flow in PV system

Throughout the year, the total amount of power generated is nearly equal to total consumption, but the daily amount of power generated is fluctuated by insolation(Shown as $\pm\alpha$). Furthermore, daily consumption can also change with the use of electric appliances, for instance, the hours lights or TV or radios are used can affect the system. (This is shown as $\pm\beta$)

If the amount of power generated is greater than consumption, the battery is fully charged and surplus power generated is lost. But, when the amount of power generated is less than consumption, power is supplied to the load from battery. In this case, depending on the conditions, battery capacity does not recover to 100(%). The PV system actually operates with an energy balance based on usage conditions and insolation conditions.

The battery capacity is as small as possible.

The condition under which the battery is used within 70% of discharge of total capacity is selected because the maintenance of the battery can be simplified and life increased.

4.2.2 Basic concept of system design

To determine the scale of a PV system, suitable system design is important. First, insolation data for the subject area is necessary. The type of electric appliances and hours of use for the load need to be assumed. The basic concept of system design is to balance the power generated by insolation and power consumption using these assumed data.

(1) Insolation data for Aleppo

With regard to the insolation data to design a PV system, the data on mean insolation in Aleppo was obtained from SSRC/HIAST PV Group. According to Table4.2-1, insolation in summer is found to be about twice that of its in winter.

Table 4.2-1 Mean insolation data in Aleppo Unit : [kWh/Day·m^2]

Tilt Angle	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
35°	3.3	4.2	5.0	5.5	6.3	6.6	6.7	6.8	6.5	5.7	4.7	3.3
45°	3.4	4.3	5.0	5.3	5.8	6.0	6.2	6.4	6.4	5.8	5.0	3.5

(2) Necessary data to set up days of autonomy

Generally, days of autonomy is an important factor to decide battery capacity. In advance, days of autonomy are assumed when designing the system. After the estimated days of autonomy have passed, the system is not stopped and should continue to supply power.

With regard to the data on days of autonomy in Aleppo, the monthly mean values for the ten years from 1978 to 1987, and monthly values for the most recent five years are shown in Table 4.2-2 below. The table shows that in the rainy season there are about five sunless days at maximum, but the mean monthly number of sunless days in one year is two or three.

Table 4.2-2 Monthly data on the days of autonomy [Unit: Day]

Year	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
1991	4	5	5	4	3	0	0	0	1	3	3	5	2.75
1992	4	5	4	3	3	2	0	0	1	1	5	5	2.75
1993	4	4	3	4	4	1	0	0	0	1	1	6	2.33
1994	5	4	3	3	2	0	0	0	0	3	5	5	2.50
1995	6	4	2	3	2	1	1	0	1	2	3	4	2.33
1978→ 1987	5.6	4.8	4.3	3.8	3.0	0.8	0.3	0.3	0.6	2.4	3.5	4.6	2.80

(3) Concept of losses in system design

A PV system is a power generation system. The equipment of a PV system such as charge/discharge controller and inverter and electric appliances has losses, respectively. The wire also has losses when transferring power. Moreover, the output of a PV is affected by temperature characteristics and surface contamination. When a system is designed, these losses need to be taken into account. Here, based on experimental data in Japan, the following rate is used for the design.

Table 4.2-3 Assumption of losses on the system design

Item			Symbol	Coeff.
PV array	Uncleanness losses 1(%) Unelectric insolation losses1(%)	Array	K1 K2	0.99 0.99
	Temperature coeff. (1,240 kW / 1,428 kW)	Temp	K3	0.87
Wiring losses of soar side	3(%)	Loss	K4	0.97
Controller		Controller	K5	0.95
Battery Charging efficiency Discharging efficiency		Charge Discharge	K6 K7	0.7 0.9
Inverter		Inverter	K8	0.9
Wiring losses of load side	3(%)	Loss	K9	0.97

(4) Basic concept to calculate PV capacity

Usually, to determine PV array capacity, The basic system design concept is to balance the power generated by insolation and power consumption at night and day while considering losses.

The capacity of an AC and DC PV system is calculated using the factor of Table 4.2-3.

For the capacity of PV array : P(kW), Power consumption in daytime : Ld(kWh/D), Power consumption at night : Ln(kWh/D), Insolation : Q(kWh/D·m^2)

*AC system

$$P(kW)= \{(Ld / K_{coef\ day})+(Ln / K_{coef\ night})\} / Q$$

$$K_{coef\ day} = K1 \times K2 \times K3 \times K4 \times K5 \times K8 \times K9$$

$$K_{coef\ night} = K1 \times K2 \times K3 \times K4 \times K5 \times K6 \times K7 \times K8 \times K9$$

*DC system (excluding the loss of inverter from AC system)

$$P(kW)= Ln / (K_{coef} \times Q)$$

$$K_{coef} = K1 \times K2 \times K3 \times K4 \times K5 \times K6 \times K7 \times K9$$

(5) Calculation of battery capacity

Basically, the power supply for the night load has priority during assumed days of autonomy. The depth of discharge in this case is taken into account in the study.

<Concept of days of autonomy>

Days of autonomy : N(Days), after N(Days), depth of discharge : D(%) is the point to stop power supply, then the battery capacity of the AC and DC PV system is calculated as follows.

a. AC system

Power consumption of N days :

$B_{AC}(kWh) = C(kWh) / ((K6 \times K7 \times K9 \times K5) \times (D(\%)/100))$

b. DC system

Power consumption of N days :

$B_{DC}(kWh) = C(kWh) / ((K6 \times K7 \times K9) \times (D(\%)/100))$

4.3 Centralized PV system

Zarzita has 42 houses and about 400 villagers. The village houses are concentrated and built in a limited area. Thus, a centralized system that concentrates PV arrays at one place is suitable for installation to supply power to the distribution network. The open area at the southern side of the village is opened to install a PV array. Design, installation, operation, and maintenance are described in this chapter.

4.3.1 Basic design of system and assumptions

(1) PV array field

The installation area nominated for the centralized system PV arrays was the southern side of the village. The field survey and interviews with the villagers were done based on the following conditions and the exact area was decided. An outline of the area is shown in Fig.4.3-1.

1) Public land is needed.
2) The site is free from any obstacles that create shadows
3) The site is relatively accessible by road in the village.
4) The site can provide an area of about 1,500m^2.
5) The slope is generally not steep.
6) The site is not used as cultivated fields or for livestock farming etc.

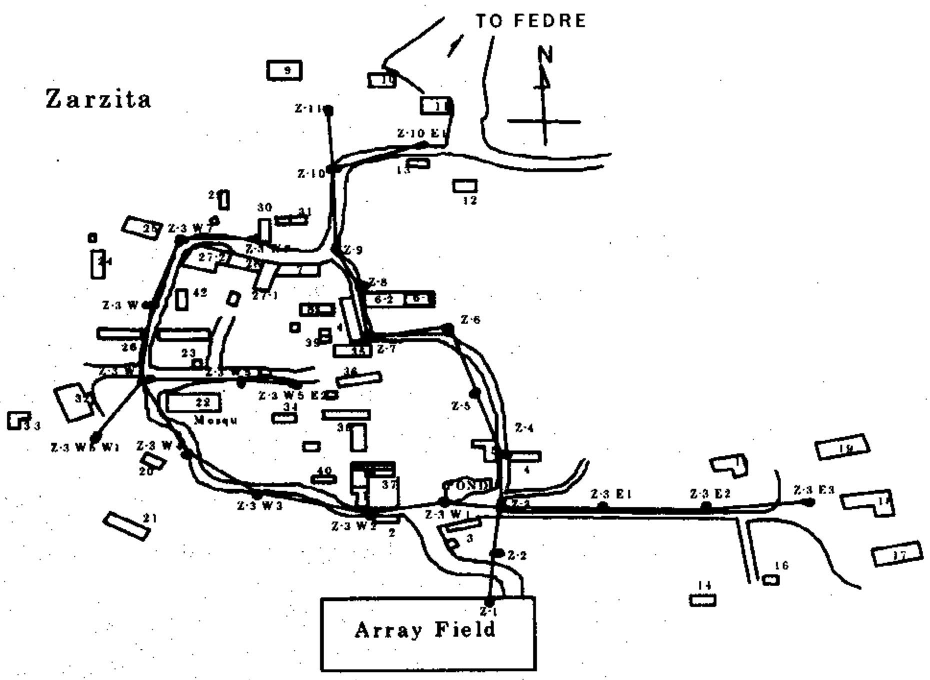


Fig.4.3-1 Centralized PV system installation site

(2) Basic items for system design

The following are assumed and selection of system equipment based on this design are given below.

1) The premises to design the centralized system
2) Type of electric appliances used by villagers and power consumption
3) Assumption to decide capacity of PV array and battery

①Premises for system design

When designing the design of the centralized system, the basic system concept was discussed with SSRC/HIAST PV group. The centralized PV system was designed based on the following items.

1) The scale of the PV system should be suitable for the minimum insolation month. When insolation increases in summer, surplus power from this system is used effectively.
2) The inclination of PV array is 35 degrees based on the average insolation. At this angle, the power generated will be maximum throughout the year.
3) Results of site survey and sustainability are taken into account.
4) The electricity is three-phase, four-wire AC 220(V) , 50(Hz).
5) The days of autonomy during the year are considered to be two days. The depth of discharge of a battery is up to 70%.
6) Japanese batteries are introduced at first. In the future, these batteries will be replaced by Syrian batteries.
7) The main equipment such as PV module, inverter, controller, and materials for distribution network system are introduced from Japan.

②Assumption of power demand

Outlines of PV and the centralized PV system were explained to the villages. The interview survey was done as for types of electric appliance, number of appliances, and required hours of use etc. The results of this survey and socio-economic survey were combined and discussed with SSRC/HIAST. The types of electric appliance and power demand of minimum insolation month were assumed as shown in the following Table 4.3-1. Moreover, regarding the consumption of electric appliances, market survey results were used.

Table 4.3-1 Assumption of power demand for the centralized system

	Load	Consumed power of each appliance	Number	Consumed power(W)	Efficiency	Practical consumed power(W)	Using time	Daily consumed power (kWh/day)
Night	Light House Mosque	 20(W) 20(W)	 200 6	 4,000 120	 0.8 0.8	 5,000 150	 6 2	 30.00 0.30
Night	Radio cassette	Radio:4(W) Cassette:15W	40	160 600	0.8 0.8	200 750	3 2	0.60 1.50
Night	TV	color:70(W) mono:40(W)	25 15	1,750 600	0.8 0.8	2,188 750	6 6	13.13 4.50
Night	Street lamp	10(W)	20	200	0.8	250	13	3.25
Consumed power during night								53.28
Day	Lighting school	20(W)	10	400	0.8	500	1	0.50
Day	R/cassette house school Cassette house school	Radio:4(W) Cassette:15(W)	 40 1 40 1	 160 4 600 15	 0.8 0.8 0.8 0.8	 200 5 750 19	 2 2 2 2	 0.40 0.01 1.50 0.04
Day	Fridge (common)	1,000(W)	4	4,000	0.8	5,000	1.5	7.50
Day	Washing machine (40 units)	160(W) (1 time /week)	6	960	0.8	1,200	2	2.40
Consumed power during day								12.35

(3) Actual design and selection of system equipment

The basic system design was based on the assumption of power demand in Table 4.3-1, the insolation data at 35 degrees in Aleppo of Table 4.2-1 and the decision-making method for the capacity of PV array and battery. The actual design of the centralized system was also based on the design concept.

As for the actual design, investigation of the materials which are PV modules, array structure, battery, inverter, controller and distribution network and suitable selection are important factors for the long life of a PV system. Therefore, circumstances such as dust and air pollution and weather conditions were taken into account.

①PV Array

Based on the assumption of power consumption in Table 4.3-1, the power consumption per day is as follows.

Day load : 12.3(kWh/Day)

Night load : 53.4(kWh/Day)

When the power consumption of loads per day is balanced with the output of the PV system at the minimum insolation of 3.3($kWh/m^2/Day$), the required PV capacity P kW is

P (kW) = 35 (kW).

The output of the PV module was considered and the components of the PV array were investigated. Based on the results, mono crystal and poly crystal modules were introduced. The centralized PV arrays combined both types of module and were connected in series and parallel as Table 4.3-2.

Table 4.3-2 Output specification of PV module and array

	Single crystal (Module)	Polycrystal (Module)	Single crystal (Sub array)	Polycrystal (Sub array)	Single crystal (total)	Polycrystal (total)
Voc(V) Open-circuit voltage	21.7	21.6	390.6	388.8	390.6	388.8
Isc(A) Short-circuit current	3.40	3.10	3.40	3.10	88.4	37.2
Vop(V) Optimum operating voltage	17.4	17.5	313.2	315.0	313.2	315.0
Iop(A) Optimum operating current	3.05	2.85	3.05	2.85	79.3	34.2
Pmax(W) Maxim output	53	50	954	900	25.8 (kW)	10.8 (kW)
η (%) Conversion efficiency	12.5	11.4				

②Battery capacity

<The concept of autonomy>

- Days of Autonomy : 3 days

  Power consumption at night for 3 days

  : 53.4(kWh) x 3 days (during the autonomy)

- The depth of discharge : Stop discharging at 70%

  Based on this concept, the battery capacity is determined as follows

- Power consumption at night for 3 days: 53.4(kWh) x 3days / (0.9x0.95x0.9x0.97)

  = 214.6(kWh)

Depth of discharge is 70% , then, the battery capacity is considered to be

214.6(kWh) / 0.7 = 306.6(kWh)

Special lead acid battery for PV use, for which data on actual use are available, was introduced. The Japanese battery of this system is planned to be replaced with Syrian battery after five to seven years, thus a compatible battery for the Syrian battery was selected and used.

This battery for PV use has the following features and an outline is shown in Fig.4.3-2.

1) Good durability and long life are expected for repeated deep discharging and charging.

2) Battery installation space is small and no special structure for installation is necessary.

3) Battery is 12V. There are few connections and it is easy to install.

4) Explosion-proof and anti-fume filters at the exhaust mouth were provided. There is no danger of back-firing inside and the gas generated when charging is returned into the case again for the battery solution.

Model	Voltage	Capacity	Weight	Quantity of electrolyte
12CT-200	12(V) At the time of full charge :15.6(V) At the time of discharge stop :11.4(V)	200(Ah) (100-hr rate)	56(kg) (including electrolyte solution)	8 (liter)

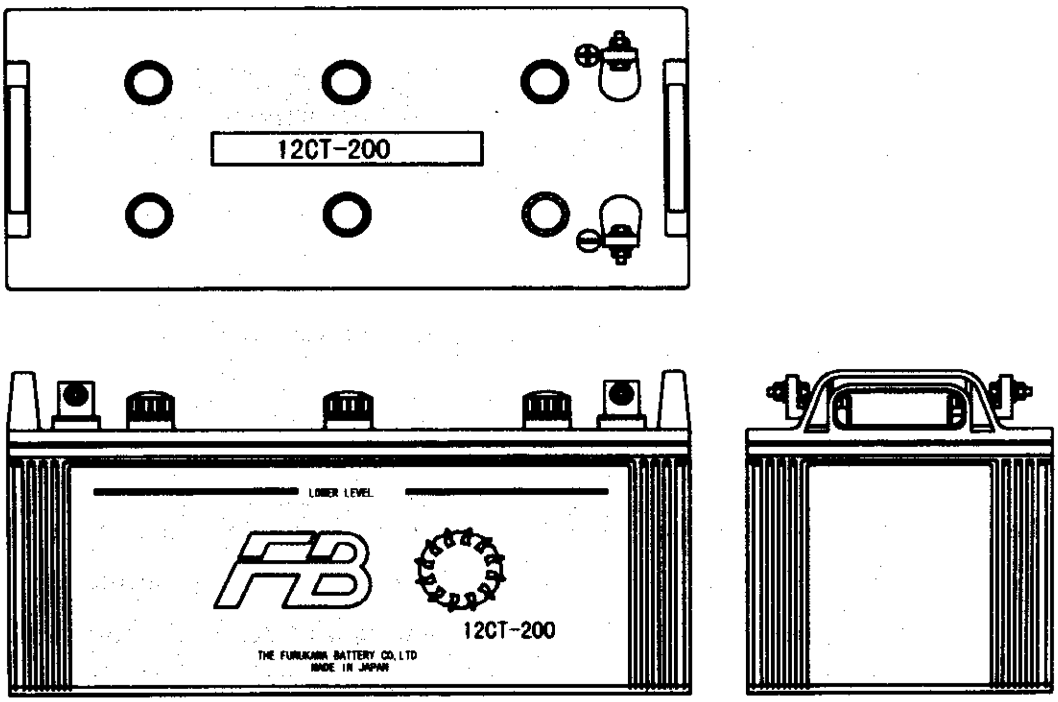


Fig.4.3-2 Battery appearance

The capacity of the battery for the centralized system is 306(kWh). The actual battery capacity is not less than 306(kWh) and the input voltage of the inverter is considered. Finally, one unit consists of 20 series x one parallel batteries

(12V-200Ah each) and the total capacity of the battery is determined as 20 series x 7 parallel = 140batteries [336(kWh)].

③Inverter

A 50Hz AC power source is used in a normal distribution network and electric appliances for AC use are widely used. The power generated by the PV system, which is stored in batteries, can use DC power. In the case of Zarzita, however, power is supplied to the respective households through the distribution network and an inverter is necessary to convert from DC to AC.

The input voltage of an inverter is DC 240(V) with series and parallel connection of the battery bank. The inverter uses IGBT (Insulated Gate Bipolar Transistor) and it can turn on and off DC power at a high speed. This switching function is used to cut DC power into the narrow rectangular forms shown in Fig.4.3-3, and the width of the rectangular form changes according to the corresponding height of the waveform below.

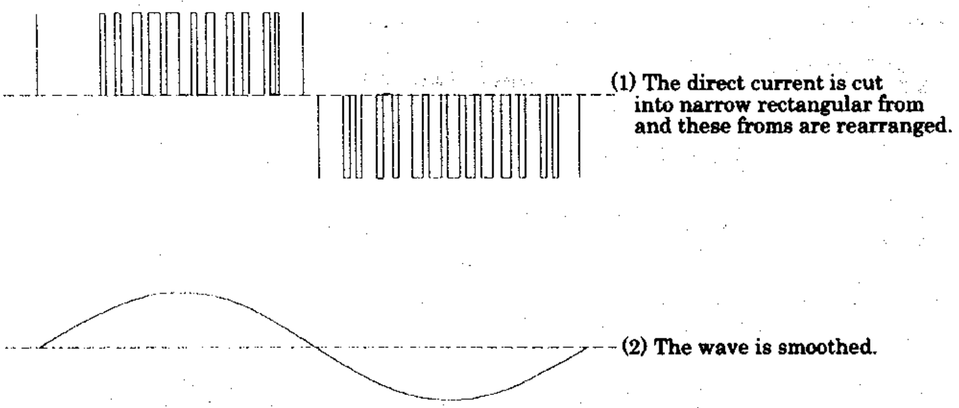


Fig.4.3-3 Principal of high frequency PWM Inverter

The inverter introduced has a grid connection function considering future expansion. When the PV system is connected to the grid, the output needs to recover 100(%) efficiently. When the rush current of a rotating machine is added, the rated capacity is 40kVA, and efficiency at the rated conditions is 92 %.

Regarding protection of independent operation, this inverter is protected by OC relays and UV relays. Moreover, the inverter has protective functions against DC over-voltage and grounding.

The basic specification of the inverter introduced is shown in Table 4.3-3.

Table 4.3-3 Specification of inverter

Item		Specification
Rating	Dimensions	Inverter :1,900x1,000x1,200 (mm) Protection device:410x280x210 (mm)
	Output power capacity	40kVA
	Input voltage range	DC0～450(V)
	Rated input voltage	DC240(V) (Operation range DC220 ～ 330(V))
	Output power	AC220(V)Three-phase Four-wier system (with insulating transformer) Voltage between phase : 398(V)
	Power conversion efficiency	±0.8pf(under grid-connection :over92(%))
	Current harmonic distortion	Total :5(%) Each degree :3(%) or less.
	Overload capacity	110(%)±5(%) (Continuous)
Main Circuit	Inverter Method	Voltage fed type / Current control type
	Switching Method	Instant Tracking Sine wave PWM
	Insulation Method	Insulated Transformer
Control System	Power control system	Maximum Power Point Tracking (Changeable to Constant DC volage control)
	Auxiliary control system	Power factor 1 control.
	Operation control system	Automatic startup/stoppage (PV output monitoring). Automatic/Manual Operation Operation conditions are changed to suit the rainy season, the dry season and weather.
	Power supply for control unit	Power by the PV array

④Operation controller

As for the operation of the centralized system, power generated is charged to the battery and discharged and supplied to households at night. The operation controller controls operation of the centralized system. The inverter has a protection function as well. Moreover, data on weather, humidity, and atmosphere temperature are input and the system is operated based on these data.

Operation control is managed according to the following items such as the voltage of the battery with the sequencer and POD(Programmable Operating Display). The total operation of the centralized system is controlled automatically.

Table 4.3-4 Setting terminal voltage of battery for charging and discharging control

Overcharge prevention		Overdischarge prevention	
Charge stop	312(V) (2.6(V)/cell,15.6(V)/battery)	Discharge stop	228(V) (1.9(V)/ cell,11.4(V)/ battery)
Charge restart	252(V) (2.1(V)/cell,12.6(V)/battery)	Discharge restart	264(V) (2.2(V)/ cell,13.2(V)/ battery)

⑤Distribution network and In-house wiring

The distribution network is planned to supply power from the centralized PV system to each household in the village. The Syrian standard was taken into account when designing this network. In the future, this network will be able to use the usual grid line without any changes when the Aleppo Electric Authority extends the grid line to Zarzita.

a. Facility of distribution network

As a result of discussions with the Aleppo Electric Authority, 26 concrete poles are used and copper wire of 35 mm^2 is used for the distribution line. Total length of the distribution line is about 970m as described below.

b. In-house wiring facility

The in-house wiring facility should meet the Syrian standard and the requirements of villagers were taken into account. The following facility was introduced considering safety and convenience.

1) Every house is provided with a watt-hour meter on an exterior wall of the house. It is used to collect electricity charges and to encourage a power-saving sense. Its location is selected for easy metering and to avoid inconvenience to residents.
2) Switch and plug sockets are installed near the entrance of the room for convenience.
3) Each room in the house is provided with a 18(W) fluorescent lamp. The brightness is about 20～30 lx.

Based on these conditions, the designed in-house wiring is shown in Fig.4.3-4.

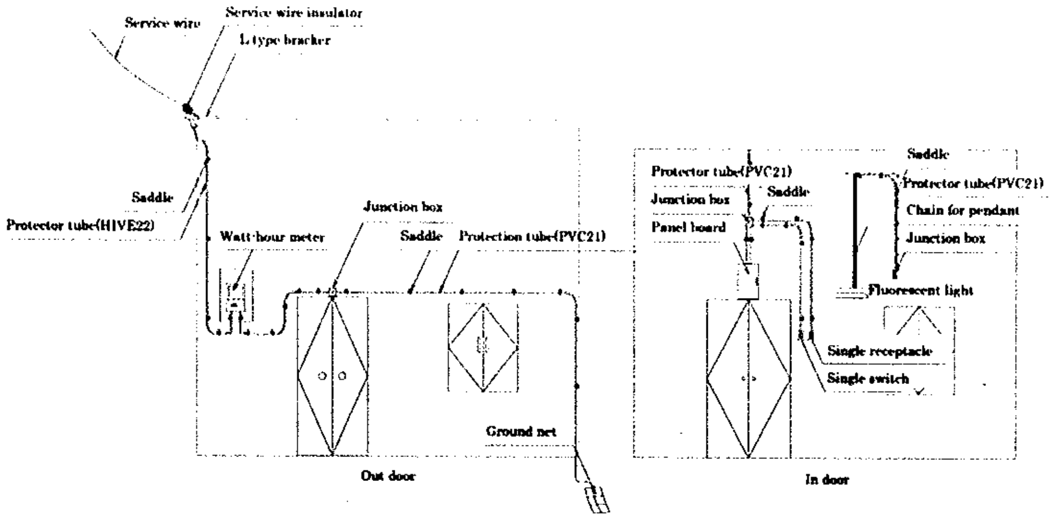


Fig.4.3-4 Basic in-house wiring circuit

(4) Features of centralized PV system

①Configuration of centralized PV system

The centralized PV system in Zarzita comprises:

a. PV array installed on a slope which faces south in the village and prepared for PV array field. PV modules are mounted to maximize the annual insolation.

b. Batteries to store DC power of PV array

c. Inverter which converts DC to AC of the commercial frequency

d. Controller to manage operation of PV system.

e. Facility of distribution network to supply AC power to households

The configuration of the system is shown in Fig.4.3-5.

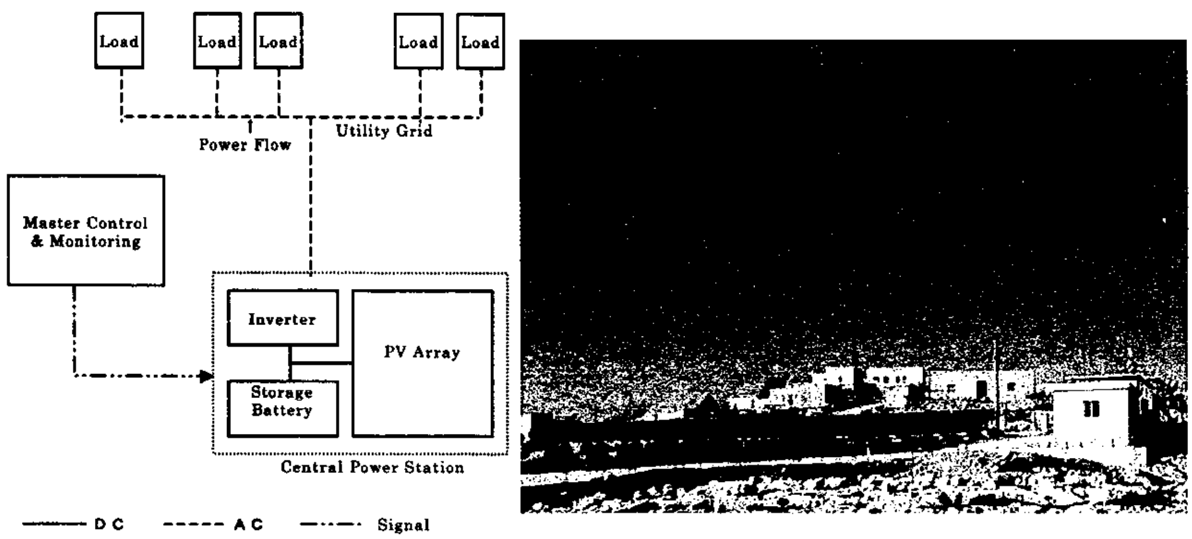


Fig.4.3-5 Configuration of centralized PV system

②Features of centralized PV system

When introducing the centralized PV system in Zarzita, the following items were considered. (1) Introduction of strings control: The PV array is divided into four groups and each array is connected or disconnected in order according to the terminal voltage of the batteries. (2) Lightning protection was introduced, because a PV array is damaged by abnormal (high) voltages. (3) Various operation modes. These are described below.

1) Introduction of strings control

On the various components of a PV system, its batteries have the shortest useful life. The useful life of batteries is closely related to charging and discharging conditions. Strings control is used to avoid overcharging.

According to this strings control, the entire PV array of the centralized system is divided electrically into four groups. Each group of PV array is turned on and off as a unit according to the terminal voltage of the batteries.

The batteries discharge power at night and the terminal voltage drops. Next day after starting operation of the system, all strings are turned on to charge the batteries. According to the charging state (rise in voltage) of batteries, the PV array is controlled in four steps. When the batteries are fully charged, three strings are turned off, and only one string remain turned on for the floating charge.

2) Effective lightning protection

As PV cells are made of single crystal or polycrystal silicon, they are very stable as long as they are used within the rated conditions. However, when an abnormal voltage is charged to PV cells, the crystalline structure is destroyed and the PV cells do not work.

In the case of Syria, as lightning occurs in winter, effective lightning protection is very important. The basic approach of lightning protection is to keep the entire PV system at the same potential, even when a lightning surge directly strikes the system or penetrates the system through the grid etc., so that no high voltage flows to PV cells or electronics parts used for control.

Bare copper wires of 35mm^2 are buried in the ground at a depth of about 30 cm around the array in the array field. This protection is shown in Fig.4.3-6. The respective modules are connected together and directly connected to earth wires.

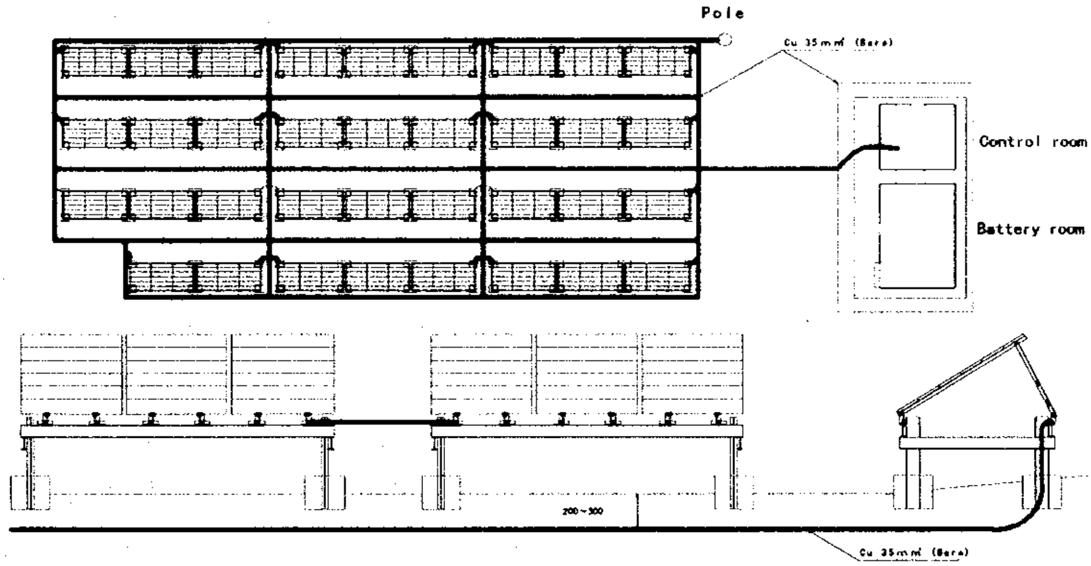


Fig.4.3-6 Layout of earth wire

At the same time, signal wires for voltage measurement and meteorological data are put into same pipe and connected to a common earth. Moreover, for the distribution network, aerial ground wire and ground wires are connected together and the arrester is provided for first five electric poles.

4.3.2 Assistance of system installation and technical transfer

For installation of a centralized system, regarding materials procured in Japan, suitable and timely guidance was instructed for custom clearance, transportation, and storage etc. For system installation, technical assistance, point of installation, and schedule management etc were advised. Moreover, before installation, the contents of installation were explained to the villagers and cooperation for this project was requested.

(1) General outline of installation

①material transportation and storage

To transport the procured materials from Latakia seaport to SSRC/HIAST Aleppo safely and quickly, we provided support concerning delivery of the materials at the port, transportation, and storage. We inspected all of the materials and prepared the inspection report for the materials and submitted it to JICA.

②Safety and health

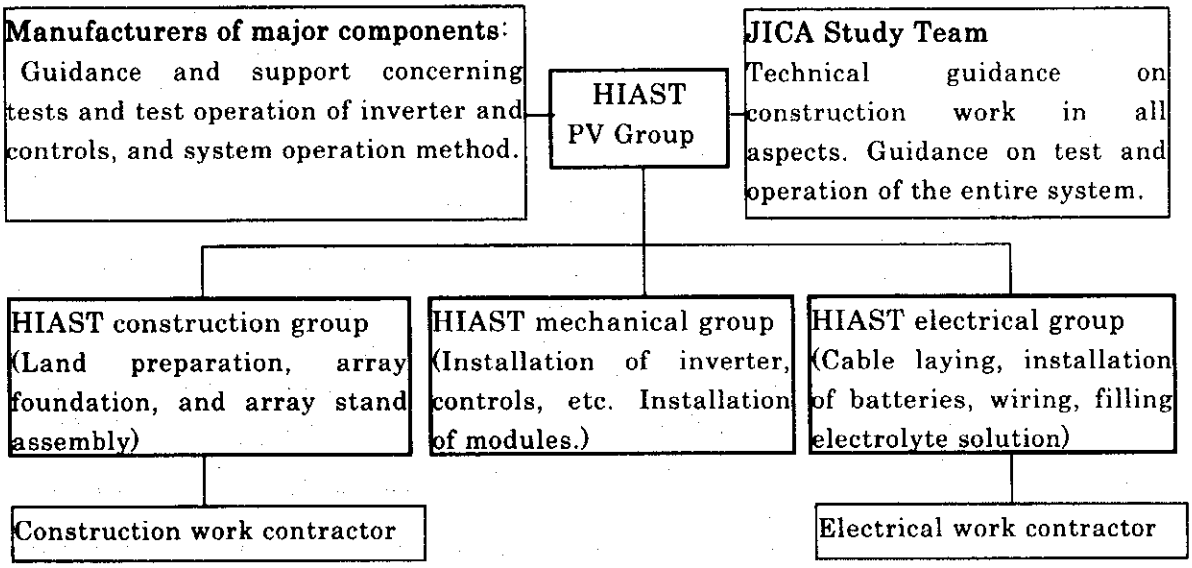
Careful guidance was given to execute all work under the principle of safety first. The standards and the regulations of Syria were complied with and Japanese standards as a reference. Sufficient meetings to review the work plan were held and all related people have a clear understanding of purpose, particulars, manning, work hours, safety measures, etc.

③Environmental measures

The installation procedure was selected to prevent pollution such as vibration, noise, and turbid water. The installation team should not intrude on the private land of the villagers. Careful guidance was given to the installation team concerning proper responses to questions of the villagers about construction work, handling of waste materials, and the environment of agricultural land and roads.

④Organization and communication for installation work

The installation work within the PV array field was supervised by SSRC / HIAST Aleppo PV group, and the study team supported this group in all aspects of the work. Organization and communication are shown below.



⑤Installation management

To install the system safety and smoothly, the following were conducted.

1) Prepared schedule with wide latitude. Made arrangements at an early stage and properly respond to any changes in the situation.
2) If there was a problem in executing the work or if arrangements are needed, the parties concerned discussed and solved the problem.
3) Made any adjustments to the schedule, if necessary, in good time. Carefully inspected and witnessed in each stage.
4) To ensure good communication among workers, the same members engaged in the work as much as possible for the same work period.
5) For any work at an elevated spot such as for extending cable, a vehicle for elevated work or footing was used.
6) If the work might have damaged buildings or facilities, provided appropriate protection with, timber, protective net, protective piping, etc.

(2) Support for installation work and technical guidance

As for actual installation work, technical assistance and guidance on the following items were provided.

	Item	Specific operation
1	Land preparation for array field	①Land preparation of the field for installation of solar arrays and a building for storing inverters, storage batteries, etc. (65 m × 25 m) ②Installation of earthing conductors for lightning protection.
2	Array foundation work	①After land preparation, holes for foundation were dug in the field. Concrete was placed to build the foundations. ②The burial depth is 250 mm or over.
3	Fabrication of array stand	①The stand is made of I sections and L sections. ②The angle of the stand can be varied to 15 degrees, 35 degrees, and 45 degrees. ③The stand materials are carefully coated with anticorrosive coating.
4	Installation of PV array stands	①The stand proper was pre-assembled and inspected before permanent assembly. The installation level of each stand was strictly controlled to ensure regular leveling of each stand. ②Each locking bolt was tightened securely, and retightened when necessary.
5	Installation of PV modules	①To carry a module, the frame was held by both hands, with the glass surface facing upward. ②The module uses a fragile material such as glass, so the module was handled with extra care. ③Because of the nature of photovoltaic cells, the module generates electricity if exposed to solar light. When wiring the module, its surface was covered with a sheet to prevent electric shock. ④Carefully controlled the number of modules installed. ⑤After installation, tightened the clamping parts and checked for any tools left behind.
6	Installation of panels	①Protected the route for carrying in the panels and the work area by means of plywood, sheet, etc. ②Examined the carrying-in route, carrying-in method, etc. To prevent any damage to the building and installed equipment. ③Carefully exercised level control of the panels installed. ④After installation, tightened the clamping parts and checked for any tools left behind.
7	Electric wire and cable laying	①Used check sheets, wiring diagram, etc. In advance to make sure all the workers knew the cable or wire laying method, splicing method, connecting points, etc. and, in turn, to prevent miswiring and misconnection. ②Kept remnants of cable as short as possible. ③Neatly laid cable without exerting any load on it. Also took care not to damage the covering. ④ If any piece of equipment was in operation, clearly indicated so. If there was any charged part, protected the charged part before starting work to prevent electric shock and wrong operation due to inadvertent contact. ⑤With regard splicing, made sure in advance that all the workers used proper splicing tools and materials. ⑥After installation, tightened the clamping parts and checked for any tools left behind.
8	Batteries	①To ensure safety during filling of the battery liquid, guidance was given on wearing rubber gloves, protective goggles, work clothes, and prevention of mixture of any foreign matter. ②Guidance was given on measurement of specific gravity and terminal voltage after filling of the liquid and after equalizing charge.
9	Various tests	①Arrangements were made in advance concerning the inspection of testing devices, methods of testing, and test items.

(3) Test and inspection

With reference to the standards in Japan, the standards in Syria were investigated. Based on those standards, inspections and tests at appropriate times during work and after completion of installation were made. All the results of test and inspection were satisfactory.

On a clear day (intensity of insolation : 70% or more from standard condition (STC)), after installation and wiring of PV modules, the open-circuit voltage and the short-circuit current were measured on each sub-array. After filling battery solution, before initial charging, the terminal voltage and the specific gravity of each battery were measured. Terminal voltage and specific gravity of the individual batteries and the battery strings, all test data were acceptable.

(4) Measurement of brightness

After the completion of installation, brightness in house in Zarzita was measured after switching on the lamp. In this measurement, the brightness of house No. 18-3 was not more than 20Lx, because of the color of walls or location of furniture. However, there was no interference with daily life.

Table 4.3-5 Measurement results of brightness

House No.	Room No.	Illuminance (lx)					Room Color	Area		Judgement
		Just under Lamp (over 20lx)	Corners					Width (m)	Depth (m)	
18	1	31.5	17.0	17.0	19.2	15.7	White	6	4	S
	2	21.7	7.5	6.0	11.0	9.1	Gray	6	4	S
	3	15.3	3.5	—	—	—	Brown	4	4	S
	4	23.0	11.0	9.2	10.0	11.3	Gray	4	4	S
19	1	23.4	10.0	12.1				4	4	S
	2	25.6	10.4	11.3	9.8	8.3	Brown	8	4	S
	3	24.0	—	—	—	—	Brown	4	6	S
	Outside Lamp	18.7	6.4							S
20	Outside Lamp	13.1	3.6							S
	1	21.0	8.5	10.3	9.8	12.2	White	5	6	S
15	1	33.9	14.3	13.0	16.2	19.1	White	6	4	S
	2	36.5	17.9	13.1	15.4	22.0	White	6	4	S
17	1	22.1	13.9	5.1			Brown	7	4	S

S: Satisfactory

4.3.3 Situation of power supply and demand

Since the start of continuous operation in September 1997, the counterpart visited every household and carried out periodical maintenance every two months. At the same time, the indication of watt-hour-meters were recorded to understand actual power supply and demand. The situation is described below.

(1) Basic concept of power supply

Before installation of PV systems, principle, features of PV systems, and usage of electric appliances were explained to the villagers to obtain their understanding and cooperation.

- Power generated is limited because the PV system utilizes solar energy. Therefore, consumable electricity is limited unlike electricity from distribution lines.
- Recommended electric appliances for a house are four lights at most, radio-cassette, and TV. Electric appliances such as irons and heaters that consume a lot of power should not be used. Incandescent lamps should not be used as well because of their large power consumption.
- Washing machines can be used during daytime and are used by groups that consist of six to seven houses. Washing is recommended to be done once a week.

Based on these concepts, the basic system operation is described below.

①One year is divided into two seasons : dry and rainy.

②The weather on a day is classified as fine or cloudy, or rains. System operation is controlled for weather conditions described above. Concretely, operating conditions are decided according to a judgment on the strength of insolation from 9:00AM～10:00 AM every day. Operating conditions can be changed.

③Charge and discharge control of batteries is limited by time.

④A watt-hour meter is installed in each house and consumption is measured. The power supply of each house is cut by a current limiter when a large amount of power is used.

The mentioned above, conditions were combined and actions such as starting and stopping the system are controlled automatically. Then power is supplied to every house of the village appropriately.

When it is rainy or cloudy during the day and batteries cannot be charged, if power is supplied to loads during the day, it will not be available at night. In such a case, the system is forced to give priority to charging the batteries, and the power supply is terminated.

The weather is judged by checking the short-circuit current of the pilot PV module.

Even if the output of PV array is below the storage power of batteries due to rainy weather, the blocking diodes will prevent a reverse current. When the weather turns good, the PV array will start to charge the batteries again.

According to this procedure for the power supply, an example of operation is shown below.

①Operating method

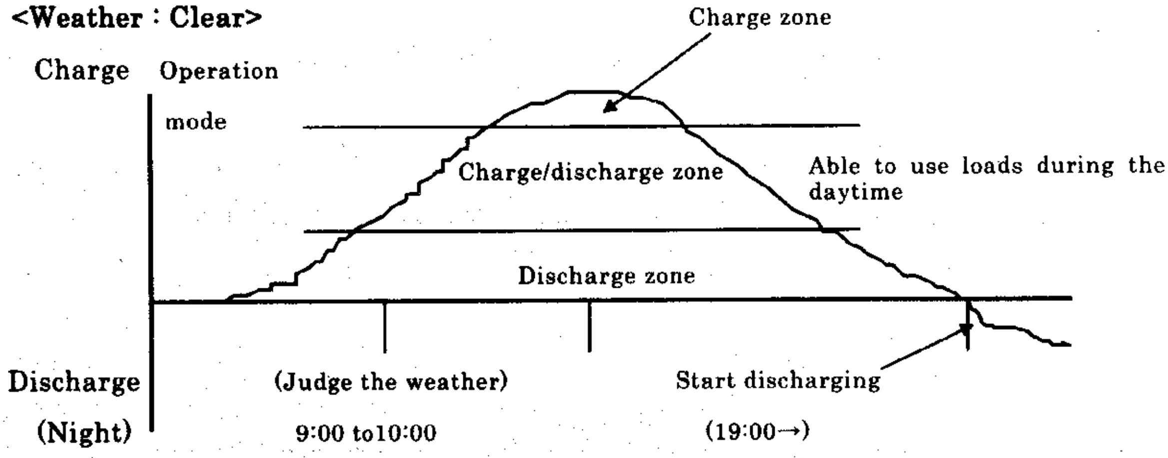
The operating method decided by conditions such as the season, the time of the day, and the weather is shown in the following table.

Table 4.3-6 Operating method decided by conditions

Item	Dry season	Rainy season
Time / Weather	AM 5:00 ～ PM 7:00	AM 7:00 ～ PM 5:00
Clear	Charge/discharge control (Able to use loads during the daytime)	Charge/discharge control (Able to use loads during the daytime)
Cloudy	Charge control only (Not able to use load during the daytime)	Charge control only (Not able to use load during the daytime)

②An example of power supply

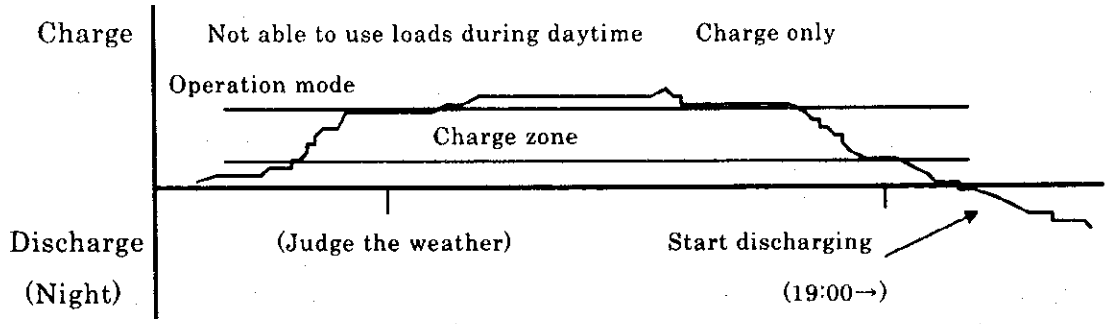
<Weather : Clear>



Operating condition is decided by the weather on the day is judged by the insolation condition between 9:00 and 10:00 in the morning. If the weather is clear, the battery will be charged and power will be supplied to the loads in daytime.

Fig.4.3-7(1) An example operation of the centralized PV system(1)

<Weather : Cloudy>



Based on the judgement on the weather, if the weather is cloudy, battery is charged prior to supplying power to the loads in daytime.

Fig.4.3-7(2) An example operation of the centralized PV system(2)

(2) Comparison of design and actual power demand

When designing the centralized system, a market survey of electric appliances and a site survey were carried out. The results of this survey and the socio-economic survey were combined and discussed with SSRC/HIAST PV group. Based on the results, the centralized PV system was designed and its scale was decided.

Total daily consumption is assumed as follows. (details are shown in Table 4.3-1)

Daily consumption = 65.65(kWh/D)

<Night consumption 53.30(kWh/D)+Daytime consumption12.35(kWh/D)>

By simple extrapolation, the total power consumption over a period of two months is calculated as follows.

65.65(kWh/D) x 60(D/2months) = 3,939(kWh/2months)

Since September 1997, actual power consumption by the villagers every two months is shown in Table 4.3-7. This consumption is the total indicated on the watt hour meter of each house.

Table 4.3-7 Actual power consumption

(Indication of watt hour meter in all house) (unit : kWh)

	97						98					
	1-2	3-4	5-6	7-8	9-10	11-12	1-2	3-4	5-6	7-8	9-10	11-12
Power Consumption	–	–	–	–	2554.2	2638.7	2619.7	2314.5	2605.1	4283.1	3929.2	3342.8
	99						00					
	1-2	3-4	5-6	7-8	9-10	11-12	1-2	3-4	5-6	7-8	9-10	11-12
	2998.4	3752.9	4686.5	7204.4	4523.7	5723.5	8902.7		5882.0	6818.0	–	–

Compared to initial assumption, from Sept. 1997 to June 1998, the assumption was lower than actual consumption. However, consumption increased about 50(%) rapidly from July 1998. After this, consumption increased in summer and decreased in winter, but, the trend of average demand is increasing every year.

(3) The comparison between estimated power generation and actual demand

Based on the insolation data obtained by the measurement facility installed in the PV array field of the centralized PV system, possible power generated is estimated and compared with the actual power demand recorded every two months from the start of operation to the present.

The result is shown in Fig.4.3-8.

In this figure,

1) Estimated generating power (Night-time load):
   Estimation when supplying generating power to night-time load
2) Estimated generating power (Day-time load):
   Estimation when supplying generating power to day-time load
3) Actual AC power generation : Summation of inverter output power
4) Actual total consumption of every house :
   Summation of readings of watt hour meter which are installed in each house.

The difference of actual AC power generated and actual total consumption of every house is the consumption of inverter and controller, street lamp, and cottage industry usage etc.

Actual AC power generated is smaller than the estimated generating power (night-time load) from the beginning of operation to December 1998. After January 1999, both data balance, and there are some cases of actual AC power generation being greater than the estimated generating power(night-time load), but actual AC power generation is smaller than the estimated generating power(day-time load). This means increased load in daytime due to use of washing machine, fan, and refrigerator.

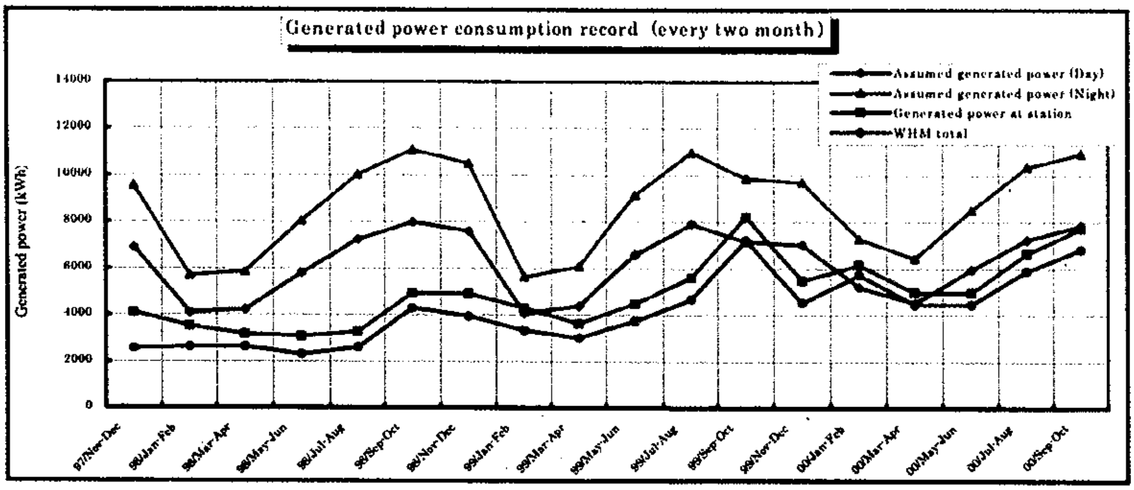


Fig.4.3-8 Transition of actual power supply and demand

In winter from November to February, estimated power generated and actual AC output power are not much different from the basic design. However, after April toward the summer, the power generated is greater than the estimated power, because of increased insolation and surplus power is generated in daytime.

Considering these data, the night-time demand is covered even in winter when insolation is low. Therefore, the PV array capacity is justifiable as it meets the design requirements. If the maximum power consumption remains the same in the future, the system will be nearly the same as the basic design.

(4) Analysis of system utilization

The operating situation of the centralized system was analyzed to the present for power supply and demand. Here, to understand how to utilize the centralized system, how much estimated generated power was used is indicated for the usage rate of insolation. This usage rate depends on the relation of battery capacity and a villager's electric appliances.

In the case of Zarzita, the insolation is low in November and December in winter and the rate of usage is always 100(%). Moreover, about 60(%) of the rate of usage is indicated in May and June when there is high insolation. Therefore, after one year from completion of installation, the situation of power supply and demand was almost satisfied. In addition, based on the results of a follow-up survey, power consumption is increasing.

In the future, for procurement and procedure to use, if reeducation and careful guidance is not given, difficulty will arise with the usage of the PV system. But, surplus power generated in daytime from March to September is utilized for the promotion of cottage industries and needs to be used effectively to improve rural areas. The trend of monthly surplus power and rate of solar energy usage is shown in Table 4.3-8.

Table 4.3-8 Rate of solar energy usage of the centralized PV system

		Month	8-10	11-12	1-2	3-4	5-6	7-8	9-10	AV.
Power Generated Assumption	a	[kWh]	6,059	3,975	4081	5,125	6,361	6,978	6,618	5,600
Power Generated at Station	b	[kWh]	4,100	3,527	3,162	3,087	3,283	4,919	4,916	3,856
Consumed Power at Customers	c	[kWh]	2,554	2,638	2,620	2,296	2,515	4,273	4,029	2,989
Energy usage rate	b/a*100	[%]	42	66	64	45	40	61	61	54
Loss rates (Inverter , etc)	(b-c-120)/b*100	[%]	-	22	13	22	20	11	16	17
Surplus power	a-c-120	[kWh]	3,385	1,217	1,341	2,709	3,726	2,585	2,469	2,490
Average DOD	b*0.8/(336*60)*100	[kWh]	16	14	13	12	13	20	20	15

[Notes]

*Street light consumption of 120kWh/ 2 months should be subtracted for loss rates calculation.

*Average DOD of batteries are calculated based on the assumption of 20% use in daytime and 80% for night/

*For average calculation, data of Aug to Oct are not included due to trial operation.

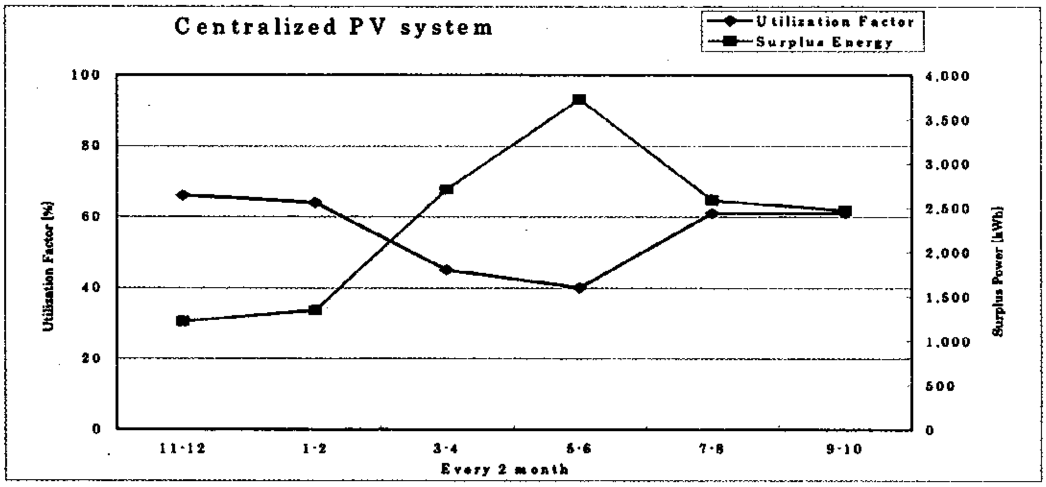


Fig.4.3-9 State of operation of the centralized PV system

(5) Study on batteries

Management of the battery has a large influence on life. Based on the actual consumption, total power consumption is assumed to be divided into 20(%) use of daytime and 80(%) for night. Then, the operation of battery for the centralized system was studied.

①Installed battery capacity : 336kWh

②Consumption and depth of discharge in winter

1) Power consumption during Nov. '97 – Apr.'98

:approx. 2,524kWh / 2 months → 42.1kWh/d

(Depth of discharge against battery capacity : 42.1kWh/d*0.8/336kWh≒10.0%)

2) Power consumption during Nov. '98 – Apr.'99

:approx. 3,365kWh / 2 months → 56.1kWh/d

(Depth of discharge against battery capacity : 56.1kWh/d*0.8/336kWh≒13.4%)

③Consumption and depth of discharge in summer

1) Power consumption during Jul. '98 – Oct.'98

:approx. 4,106kWh / 2 months → 68.4kWh/d

(Depth of discharge against battery capacity : 68.4kWh/d*0.8/336kWh≒16.3%)

2) Power consumption during May. '99 – Oct.'99

:approx. 5,573kWh / 2 months → 92.9kWh/d

(Depth of discharge against battery capacity : 92.9kWh/d*0.8/336kWh≒22.1%)

20% of depth or less of discharge of power consumption is acceptable for daily cycle services and life of about seven years is expected. However, depth of discharge is over 20%, this is slightly deep for daily cycle services.

In particular, during the two months of July to August 1999, power consumption recorded a maximum of

[about 7,200kWh/2 months→120.0kWh/day]

[depth of discharge :120.0kWh/day x 0.8 / 336kWh≒28.6%].

For example, the relation between depth of discharge and battery life is shown in Fig.4.3-10. The characteristics of a battery should be understood when referring to this figure and for the purpose of maximizing the life of the battery, careful guidance on power saving and effective use of electric appliances is necessary.

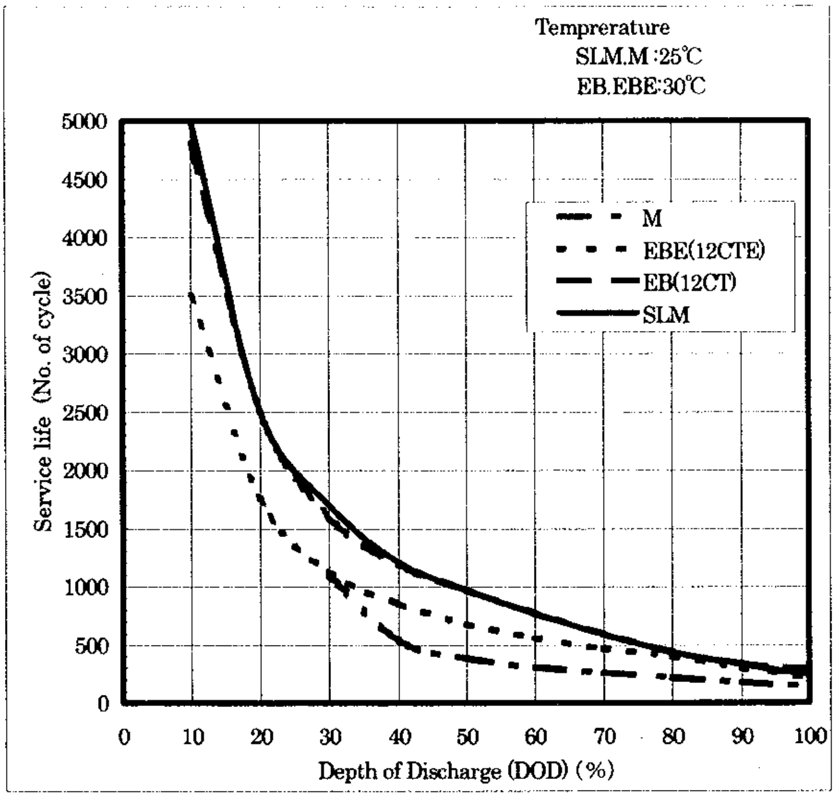


Fig.4.3-10 Depth of discharge vs. service life of battery

(6) Inverter capacity

The capacity of the installed inverter for the centralized PV system is 35kW, which seems to have a small margin against current peak load of about 20.5kW.

As for the trend of electric appliances in Zarzita, refrigerators, washing machines, and other electric rotating machinery are increasing. These machines have a rush current of seven to ten times as much as the rated values during startup. Therefore, the inverter should have enough capacity to take up these rush currents.

The inverter installed has a function to connect to the grid line when it is extended to the village in the future. Thus, if the inverter has a capacity comparable to the total capacity of the PV system, it will be able to send power in excess of demand to the grid line, maximizing capacity utilization. While the inverter seems to have a small margin at present, its capacity is justifiable considering future expandability.

(7) Transition situation of power supply and demand of respective houses

The transition situation of power consumption, which is checked during periodical maintenance every two months for each house, is shown in Fig.4.3-11. According to this figure, the trend of power consumption of each house is indicated to reduce in winter and increase in summer respectively. Moreover, in Zarzita, houses are classified into three categories by power consumption trend : increasing, increased and saturated, and not increased much.

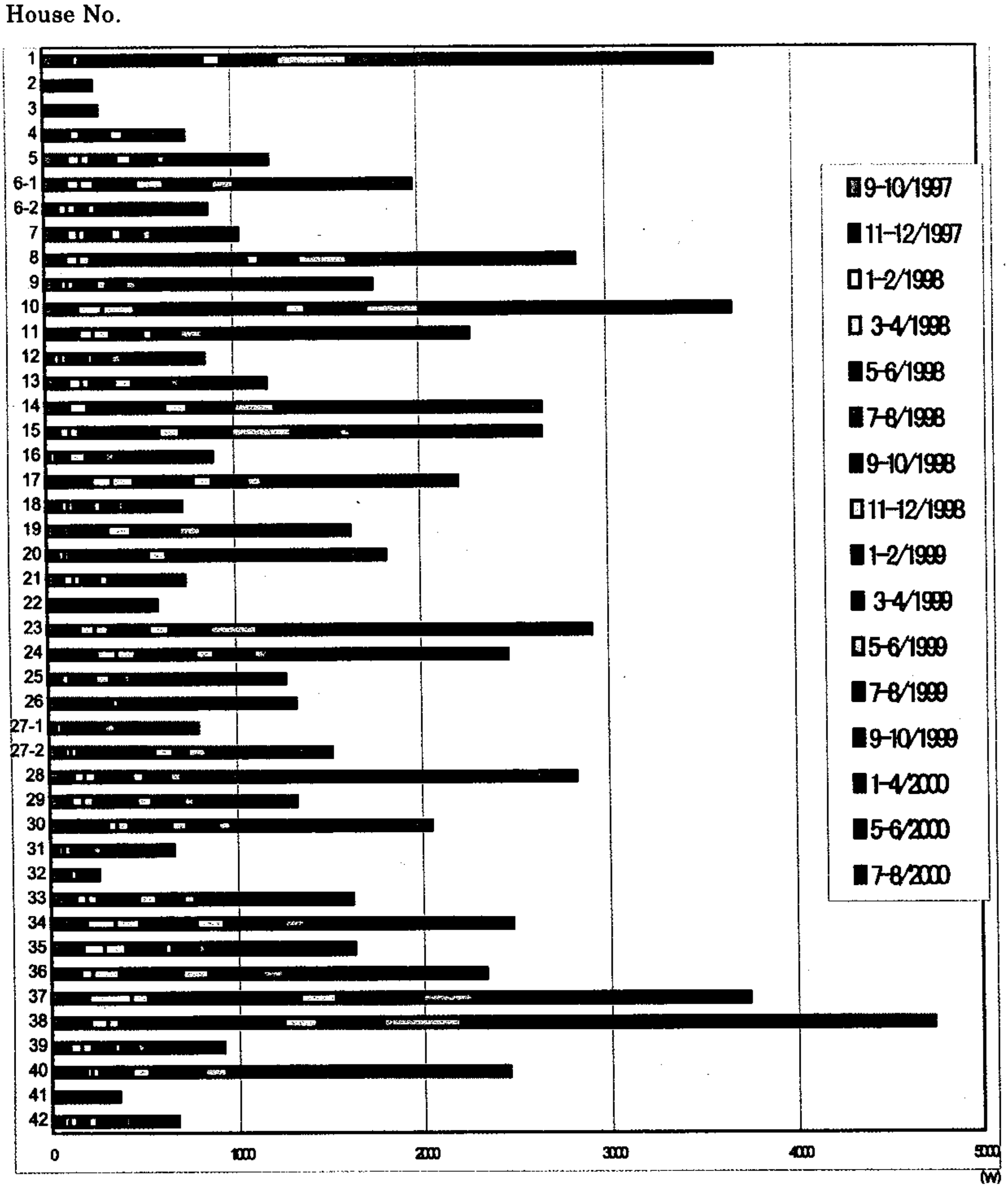


Fig.4.3-11 Transition of power consumption for each houses in every two months

(8) Power consumption of monitor houses

In Zarzita, other than using the watt hour meter, four typical houses were picked up based on family members and room arrangements, and have a data logger installed for collecting data on how they are consuming electricity. The features of these four houses are shown below.

Table 4.3-9 Selection of house with data logger installed

No.13	There are two rooms. They have one TV and radio respectively. This house has the average room arrangement and electric appliances. It seems that the power consumption pattern of other houses can be understood by doing a continuance investigation.
No.14	There are three rooms. They had already TV and radio. Washing machine, refrigerator, and fan were purchased. The increase of electric appliances is remarkable though this house is as typical as No.13. There are three rooms.
No.16	There is one room and a small family. This is a comparatively small family in the village and small power consumption is expected in the future.
No.37	There are eight rooms and a big family. A high power demand was forecast at first.

The changing situation of power consumption at representative houses was totaled by month and is shown in Fig.4.3-12.

According to this situation of power consumption,

①No.13 and No.16

In winter, consumption increases and in summer it decreases. Throughout the year, it averages comparatively little consumption. In particular, consumption is low in No.16. It is considered that a small increase of electric appliances is taken into account.

②No.14

Consumption is 100-120(kWh/month) in summer. In winter, consumption is 40-50(kWh/month) and average. However, consumption increased since May, 1999. Electric appliances with large power consumption such as refrigerator and washing machine were purchased.

③No.37

Power consumption increased from August 1998. The average consumption did not decrease after August 1998. The night base load increase with the purchase of a refrigerator and electric appliances such as iron and fan, which have a large consumption.

These families are picked up as a sample in Zarzita. This village has a house where power consumption is greater than that of sample houses and there are few houses in the village. Not only the sample house but also a house excluding this should continuously check consumption in the future.

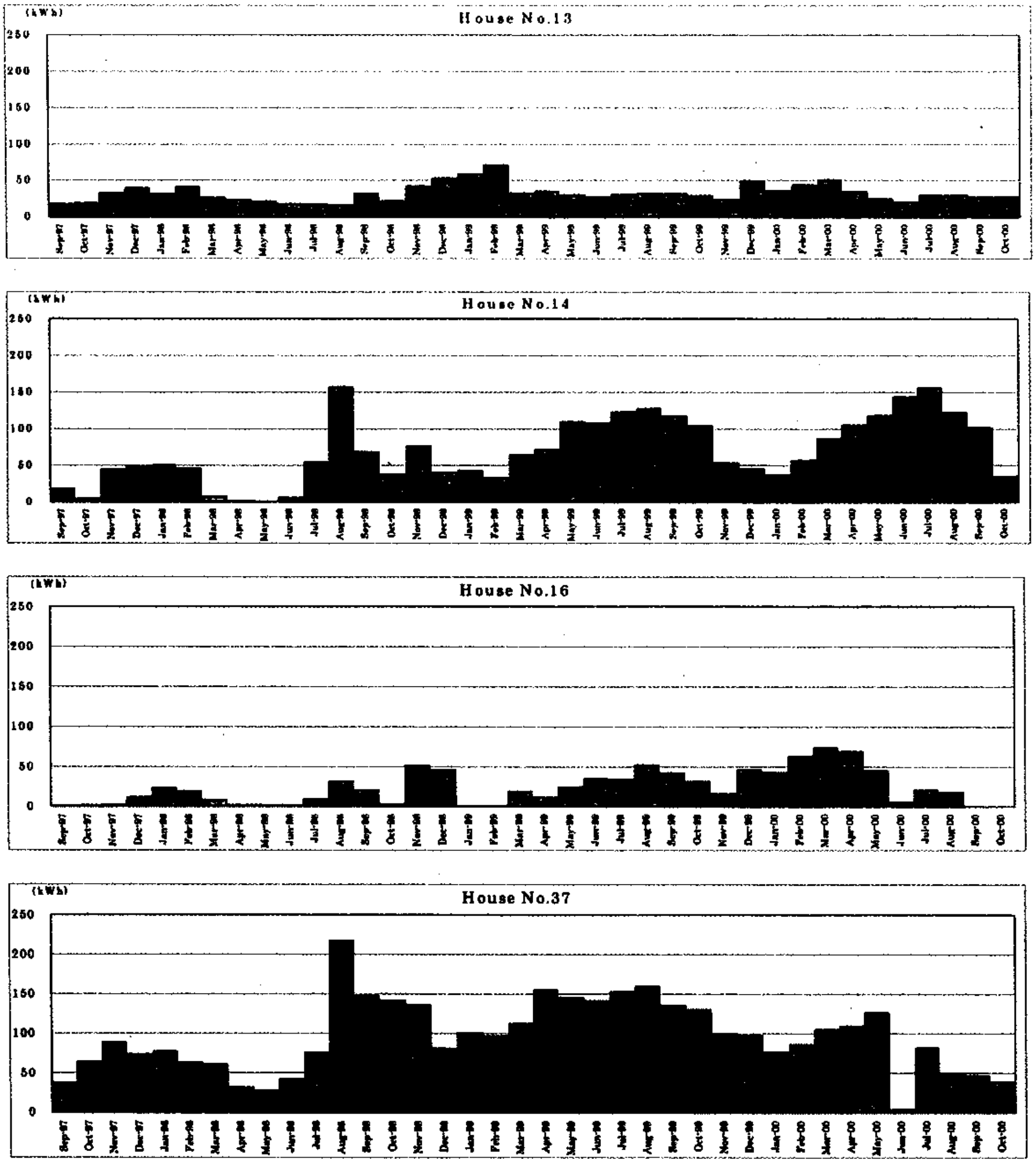


Fig.4.3-12 Power consumption state of houses where data logger installed

(9) Change in electric appliances owned

Since its September 1997 commissioning, the SSRC/HIAST PV group has been checking the electric appliance holdings of each house every six months by taking advantage of the periodical inspection.

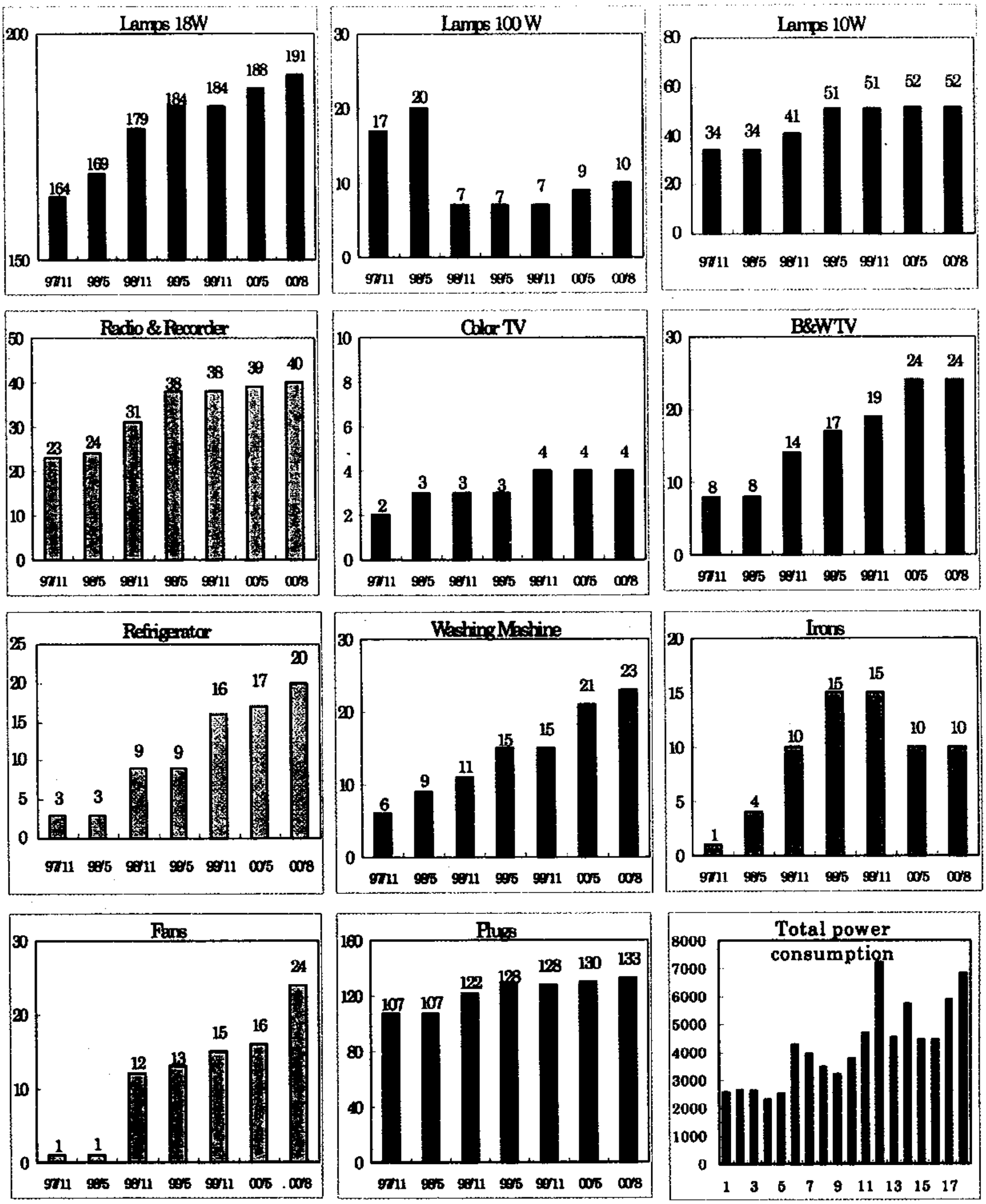


Fig.4.3-13 Transition of electric appliance holdings for each house

4.3.4 Maintenance

(1) Basic maintenance check items

Daily check and periodical check are considered to be basic maintenance checks. With the exception of this maintenance, trouble-shooting during system operation is important as well. The basic idea of this is shown here. Refer to the maintenance check manual for details.

①Daily check

For each system, daily check is executed to understand normal operation accurately and to judge small changes and prevent abnormalities from occurring. Mainly, visual inspection and the voltage check of each part with a tester. are executed daily. The results of checks should be recorded.

②Periodical check

Periodical check is executed to check details that cannot be checked easily in the daily check. Also, this check ensures safer system operation. After the battery is fully charged, this check is executed after the system stops completely. Periodical checks are executed about once every two months basically and the results of checks should be recorded.

③Trouble-shooting

The villagers solve small problems such as changing light tube and switch of the fluorescent lamp. However, a major problem such as system failure is handled by the Electric Authority under the supervision of SSRC/HIAST. Every system has a protective function against failure. When a failure occurs, the system is stopped a safe way.

(2) Executing maintenance

The daily check is usually a visual inspection and many check items are duplicated by the periodical check. Thus, the periodical check is mainly described here. The maintenance manual submitted for each equipment by the manufacturer is taken into consideration. Through installation work and trial operation, a more realistic maintenance manual is studied with the SSRC/HIAST PV group. Maintenance of the centralized and individual systems is executed according to Table 4.3-10.

Table 4.3-10 Inspection items

Equipment	Item	Inspection	Objective system
PV system	PV array	Check of voltage and current of PV array (by using I-V curve tracer, etc.) (open-circuit voltage (Voc) & short-circuit current (Ioc) or operating current (IOP))	All system
		Cleaning of PV array and module	
	Battery	Measure battery terminal voltage, charge current, electrolyte level and specific gravity ; making up for loss of electrolyte water	All system
		Clean battery case	Individual
	Floating charge control unit	Record readings of voltmeters, ammeters, and other instruments Check parameters Check performance with terminal voltage and indicator lamp Clean panel inside and outside	Centralized Individual Medium scale
	Inverter	Check of performance with terminal voltage and indicator lamp Clean panel inside and outside	Centralized Individual Medium scale
	Data logger	Download of logged data, and replace battery of data logger	Centralized
Facility of Distribution line	Distribution line	Visually inspect pole, insulator, and distribution line	Centralized
		Measure earthing resistance	Centralized
	Drop cable	Visually inspect drop cable	Centralized
Facility of In-house wiring	In-house wiring	Record reading of Watt-hour meter of each home Visually inspect indoor wiring Take inventory and record electric appliances in each home Record failures	All system (Watt-hour meters are for just only centralized system)
	Data logger	Download data from the data logger of each sample home ; Replace battery of data logger	All system

(3) Results of maintenance for each system

When a site survey was executed, operation control and maintenance executed by SSRC/HIAST PV group were checked continuously. The execution situation and the results of maintenance are described below.

① PV arrays

PV modules, support structures, and cables were all in good working condition. The PV array open-circuit voltages were recorded as almost constant in the range of 330(V)~380(V) depending on weather conditions. PV circuit was judged to be in good working order.

②Controllers

The breakers and sequencers etc in the controller had no problems electrically and mechanically. The panel instruments were also in good condition.

In addition, control and protection functions, etc., were examined and no problems had occurred.

③Inverter

No electrical and mechanical problems occurred. Throughout this project, the inverter kept a nearly constant voltage level in the range of AC225～235(V), depending on load conditions. This voltage range satisfies the design voltage (AC230(V)±5(%)(±11.5(V)).

Moreover, electronic parts are installed inside, but maintenance is sufficient.

④Battery

The battery is a lead acid battery.

12(V)-200(Ah) : solution about 10 liters/battery, 20 series x 7parallel → 140 batteries are installed.

Neither mechanical damage nor solution leakage was noticed. Batteries in which solution level was found to be reduced were refilled with distilled water. The following shows the track record of the refilling service since the start of operation.

Table 4.3-11 Filling of distilled water for battery

Year	Sep +Oct	Nov +Dec	Jan +Feb	Mar +Apr	May +Jun	Jul +Aug	Water ℓ/year	Water ℓ/ batt·year
Sep/97 to Aug/98	100	0	0	60	116	240	516	3.68
Sep/98 to Aug/99	215	127	15	81	289	200	854	6.1
Sep/99 to Aug/2000	257							

In summer, based on Table 4.3-11, the battery solution depleted faster than in the other season. In particular, about 60% of the rated volume of solution was refilled through fiscal year 1999. The trend of average power demand is increasing centering on the summer. Most power consumption is concentrated at night with little demand in daytime. On the other hand, insolation in summer is about twice that in winter so, after night consumption is charged, a floating charge is continued. Therefore, battery solution is depleted faster as atmospheric temperature increases. After discussions with the SSRC/HIAST PV group, the following measures were taken.

1) Usually, a periodical check is carried out once every two months. However,

battery inspections, including the trend of solution level and specific gravity, are executed every month during summer (May to October).

2) In summer, voltage setting for charging is adjusted while monitoring night consumption and charge during the day.

4.3.5 Examples of problems and trouble-shooting

The faults and trouble-shooting are described below. The system installed had no problems, but just after commissioning the following occurred.

1) Short between + and – caused by twisting of both polarity cables
2) Short-circuit caused by having inserted wire in wall outlet
3) Electric leakage when washing wall with water

The problem was seen to be caused by a lack of knowledge of electricity among villagers. The SSRC/HIAST PV group instructed and educated the villagers repeatedly and the situation improved.

Table 4.3-12 Centralized PV system problems and trouble-shooting

Date	House No.	Fault	Cause	Repair
20/8/97	Grid	Z1 Pole is Broken	A truck crushed the grid	Install a new pole
22/9/97	Grid	(Inverter fault) station is stopped	Short between T phase and neutral caused by a child during ceremony day decoration.	Remove the shortness
28 /8/97	10	Breaker (3A) for plugs is off	Using Iron (1000w)	-
29/8/97	15	WHM is out of order	Broken	Replace it by a new one
29/8/97	33	ELB is off	Washing the walls.	-
1/9/97	11	ELB is off	A child inserts a bare wire in the plug.	-
5/9/97	22	Sound from a plug.	Screws are not tightened.	We tightened the screws.
5/9/97	22	Fluorescent lamp is not working.	It needs a good fixing.	We turned It and fixed it.
1/10/97	29	ELB Is out of order.	One spring is out of its place.	Replace the spring inside ELB.
20/10/97	6-1	ELB Is off and sparking when switch It on.	Short Inside A Plug between wire and screw.	remove the shortness.
5/1/98	4	Lamps breaker is off when sitting room lamp switch is on.	Short inside the lamp set.	
5/1/98	6-2	Plug breaker is off.	Short between wires.	
2/2/98	37	The lamp in the sitting room is off	Lamp is burnt	

WHM : Watt Hour Meter
ELB : Earth Leakage Breaker