CHAPTER 2
TARIAT SUM,
ARKHANGAI AIMAG

CHAPTER 2 TARIAT SUM, ARKHANGAI AIMAG

2.1 Pilot Plant Site and Surrounding Condition

Tariat Sum of Arkhangai Aimag is located on the highlands of Mongolia, north 48° 09’ east 99° 53’ and 625 km away from Ulaanbaatar. The population of Tariat Sum is 5,985. A pilot plant has been installed beside a hospital and supplies generated electricity to the hospital. The position of pilot plant equipment was planned to be in the protected area of a lightning rod. In addition, the position of the wind turbine was considered to avoid turbulence caused by obstacles such as buildings or trees in upwind. The position of the PV array was selected to be out of the shadow area of the wind turbine and other buildings. Photo II.2.1-1 shows the pilot plant in Tariat Sum and Figure II.2.1-1 shows the plot plan of pilot plant equipment.

Photo II.2.1-1 Pilot Plant in Tariat Sum

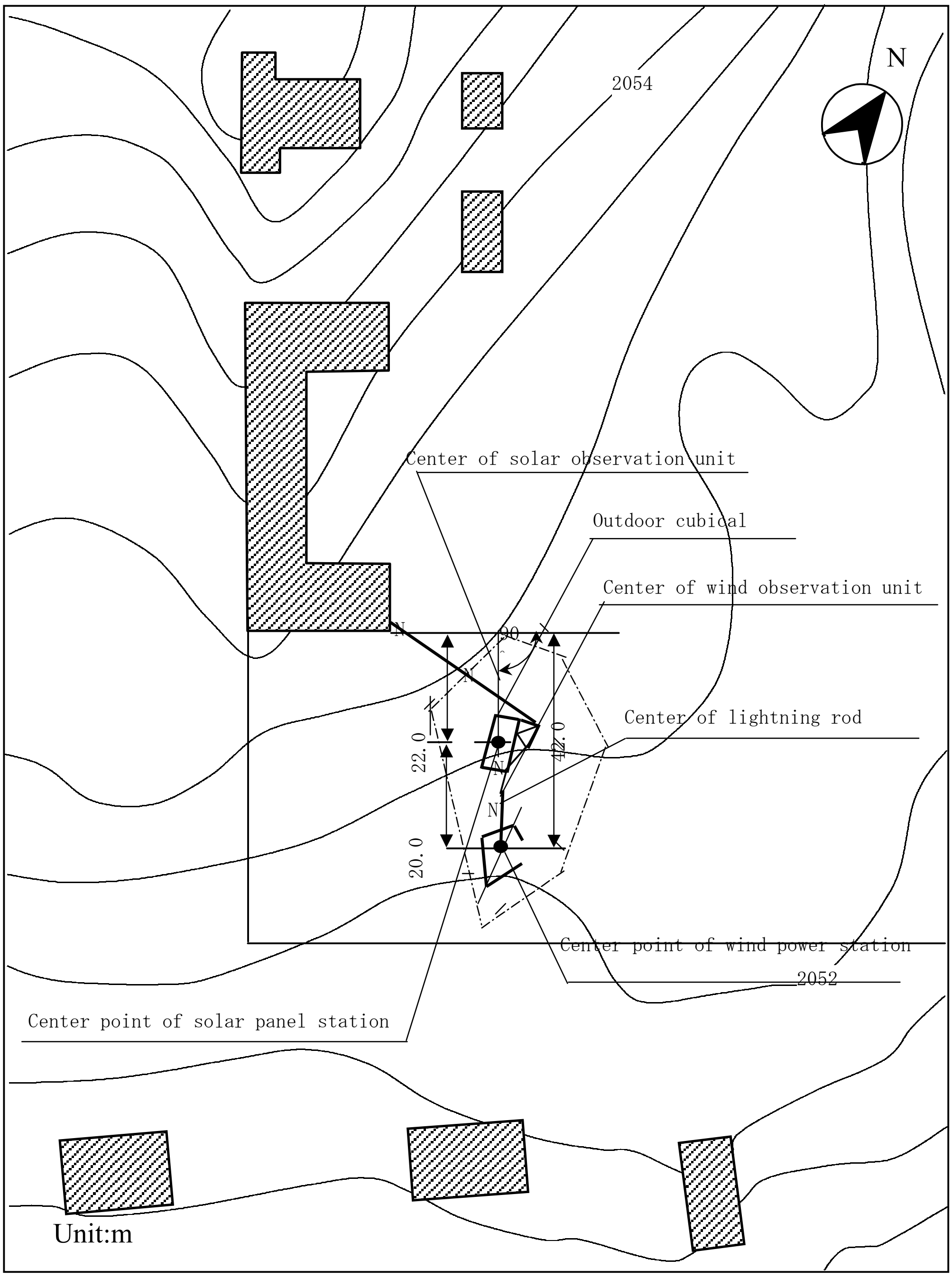

Figure II.2.1-1 Plot Plan of Pilot Plant (Tariat)

2.2 Calculation of Generation Capacity and Power Output

2.2.1 PV Power Generation

In Tariat Sum, power output by using PV system (installation angle is 65 degrees and 100 % output) was estimated on the basis of solar irradiation data at Tsetserleg where the capital of Arkhangai Aimag is located, because the data are not available at Tariat Sum center. The solar irradiation data at the pilot plant has been collected since July 1999. Both solar irradiation data, from the Meteorological Department and pilot plant, are compared to clarify the difference. Table II.2.2-1 shows actual power output and estimated output of the PV system on the basis of solar irradiation data that was collected by the Meteorological Department and pilot plant.

Table II.2.2-1 Power Generation by PV System Against Standard Generation and Comparison of Measured Average Global Solar Irradiation Level

Item	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Standard average global solar irradiation* (kWh／m^2・day)	4.3	4.0	3.8	3.2	1.7	1.1	1.6	2.6	3.9	4.4	5.0	5.1
Estimated average generating power (kWh／day) (Calculation based on standard average global solar irradiation)	11.8	12.9	15.6	18.6	13.9	10.2	14.2	18.3	18.3	15.2	14.2	13.5
Actual measured average global solar irradiation** (kWh／m^2・day)	6.5	5.5	4.5	3.2	2.1	1.4	1.9	3.1	4.4	6.0	6.6	6.4
Actual measured average generated power (kWh／day)	12.3	13.8	13.9	14.1	14.7	10.7	12.1	14.1	14.0	17.2	14.2	12.2
Estimated average generating power[1] (kWh／day) (Calculation based on measured average global solar irradiation)	17.2	17.5	18.6	18.9	17.5	13.5	17.2	21.6	21.9	20.9	18.6	16.6
Theoretically average generating power[2] (kWh／day) (Calculation based on measured average global solar irradiation)	14.6	14.8	15.8	16.1	14.9	11.5	14.6	18.4	18.6	17.7	15.8	14.1
Ratio of average global solar irradiation (Measured／Standard)	1.51	1.38	1.18	1.00	1.23	1.27	1.18	1.19	1.12	1.36	1.32	1.25

1 Estimated average generating power: Computed inclined solar irradiation on the base of global irradiation and multiplied by total array capacity。
2 Theoretical average generated power: On the base of measured global solar irradiation, estimated average generation power is computed considering deviation from Pmax point, dirtiness of surface of module, deterioration and so on
* A standard average global solar irradiation is the data of Mongolian Meteorological Agency from 1988 to 1997 years (10 years average).
** An actual average global solar irradiation is the data recorded at pilot plant site from July 1999 to June 2000.

From the above table, it could be understood that the difference in the ratio between standard and measured average global irradiation differs every month and on average it becomes smaller as winter approaches. The amount of actual measured average power generation increases gradually after the installation, and showed the maximum value in April 2000. The actual measured value of the generated power shows a value closer to the theoretically computed generating power. Possible causes of difference in the standard and the measured average global solar irradiation data are the difference in the measurement years, in the measurement point, possible recording error of the observation staff, yearly differences in the weather conditions and so on. In the case of actual measured generated power, theoretically, even if a system has power generating ability, when the voltage of the storage battery reaches an over-charging prevention point or when a storage battery becomes fully charged and load isn't used, it disconnects the PV array to protect the storage battery. Due to this possible reason, the amount of actual measured generated power is smaller than the amount of theoretically generated power.

2.2.2 Wind Power Generation

Power output from wind turbine is estimated on the basis of average wind speed by the Meteorological Department. The power output, which is estimated on the basis of wind data of the Meteorological Department and pilot plant, is compared. Rayleigh distribution, a kind of probability density function, was used for power output estimation from wind turbine. Table II.2.2-2 shows the difference of actual and estimated power output on the basis of Meteorological Department data and pilot plant data.

Table II.2.2-2 Power Generation by PV System Against Standard Generation and Comparison of Measured Average Global Solar Irradiation Level

Tariat	1999 Jul	Aug	Sep	Oct	Nov	Dec	2000 Jan	Feb	Mar	Apr	May	June
Average wind speed (M/H department data) (m/s)[1]	2.1	2.1	2.4	2.4	2.7	2.3	2.4	2.3	2.6	3.4	2.9	2.4
Estimated power generation (M/H department data) (kWh/day)	0.1	0.1	0.5	0.5	1.1	0.4	0.5	0.4	0.9	2.7	1.5	0.5
Average wind speed (Pilot Plant data) (m/s)[2]	2.9	3.3	3.9	4.6	4.7	4.7	4.1	4.8	4.7	5.1	4.3	3.2
Estimated power generation (Pilot Plant data) (kWh/day)	1.5	2.4	4.1	6.3	6.6	6.6	4.7	7.0	6.6	8.0	5.3	2.2
Actual power output (kWh/day)	0.5	1.1	2.1	1.8	2	1.3	0.5	1.2	1.5	3.0	2.1	0.9
Pilot Plant／M/H data	1.4	1.6	1.6	1.9	1.7	2.0	1.7	2.1	1.8	1.5	1.5	1.3

*1 Average data of Mongol Meteorological Agency is from year 1988 to 1997.

*2 Data of Pilot plant from July 1999 to June 2000.

Table II.2.2-2 indicates the monitor of wind speed in Tariat has a tendency to record the wind speed smaller than the actual speed. The difference between actual power output and estimated power output is caused by the system of pilot plant. To protect storage batteries, the power is consumed by dump load when battery voltage reaches over charging prevention voltage or is fully charged with no load. Therefore, the actual power output becomes smaller than that of estimated output.

2.3 Load of the Pilot Plant Facility

In Tariat Sum, generated electricity from the pilot plant is being supplied to a hospital because Tariat Sum requested the hospital as a pilot test facility. The main load of the pilot facility is fluorescent lamps for operation and treatments at night. The other loads are DC input refrigerators, audiovisual equipment such as televisions and video decks. An electric kettle was supplied to the hospital due to the necessity of a water heating system for emergency cases despite the high power consumption. Those loads are selected to have balance with power output in winter when power output estimation is lowest throughout the year. Table II.2.3-1 shows expected power output by PV-Wind hybrid system. Table II.2.3-2 shows load capacity and estimated power consumption.

Table II.2.3-1 Expected Power Generation from PV - Wind Hybrid System.

	Expected power generation from Wind turbine (kWh/day)	Expected power generation from PV array (kWh/day)	Total power generation (kWh/day)	Inverter output(1) (kWh/day)
Tariat	0.79	11.43	12.22	8.52

(1) DC refrigerator power consumption (1.56kWh/day) and)Inverter loss 80 %

Table II.2.3-2 Load Capacity and Estimated Power Consumption

Load	Load Capacity		Daily utilization (Winter)		Consumption Power (Wh)
	No.	W	Hours	Time period	
Lighting					
Room	7	40	12	5:00～9:00 16:00～24:00	3,360
Corridor	5	20	17	6:00～23:00	1,700
Toilet	1	20	5	--	100
Television	1	75	6	--	450
Video-deck	1	20	3	--	60
Electric kettle	1	2,000	1.2	--	2,400

Total 8,070（Wh）

（Source ： JICA Study Team, Site survey）

2.4 Power Distribution Equipment and Electrical Wiring

2.4.1 Power Distribution Equipment

Power distribution equipment for the pilot plant was arranged in Mongolia. As an example, electrical lines that connected the PV array and wind turbine to the cubicle was settled underground. The cables are shown as follows.

- Wind turbine to Cubicle : 38 mm^2, 3 core cable, single line
- PV array to Cubicle : 22 mm^2, 3 core cable, double line

2.4.2 Electrical Wiring

Settled electrical new wires prevent accidents caused by existing old wires. Those wires were connected to only new provided electric equipment due to limited power output from the system.

Figure II.2.4-1 shows the internal electrical wiring of the pilot plant at Tariat Sum.

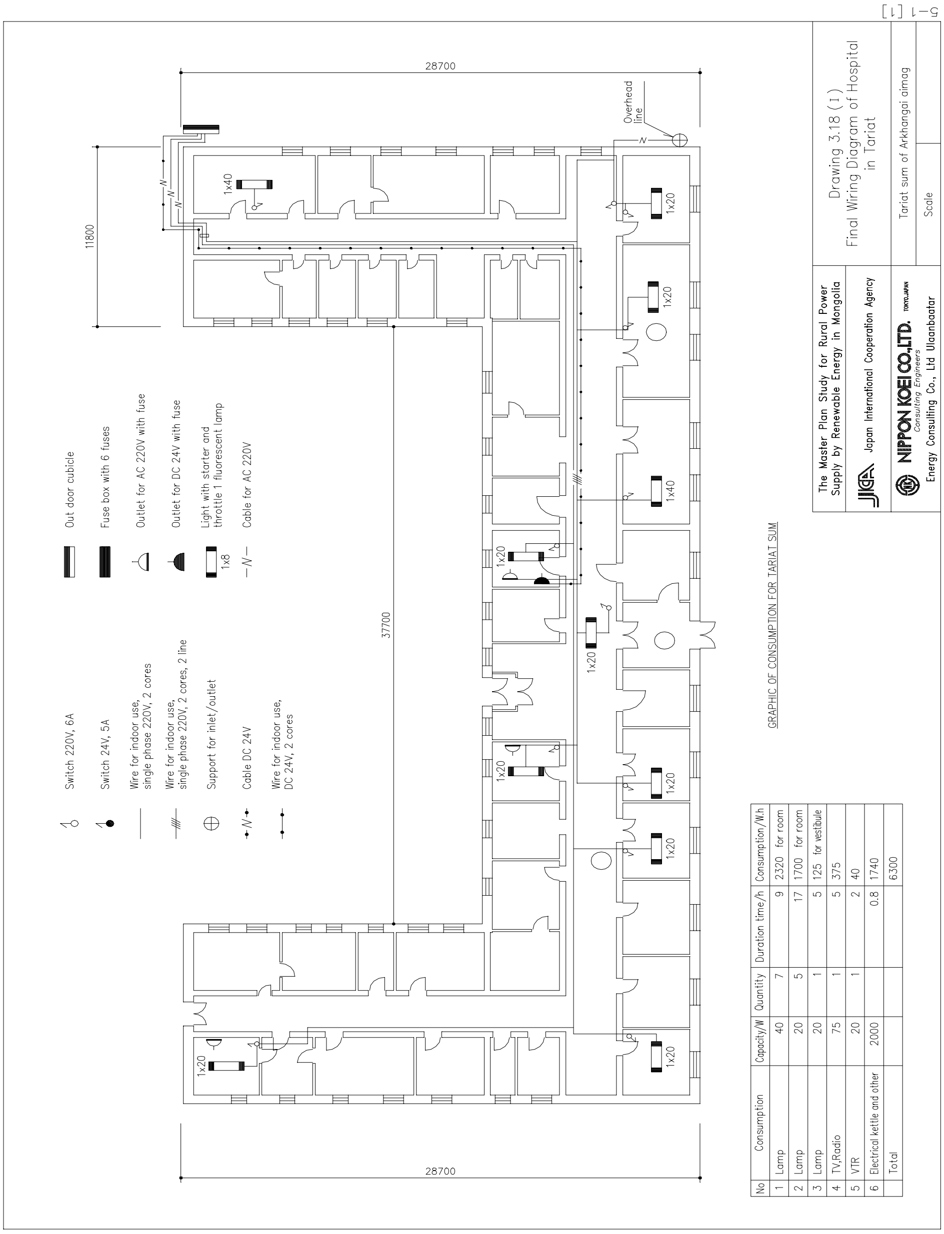

Figure II.2.4-1 Electrical Diagram of Tariat

CHAPTER 3
BAYAN-UNDUR SUM, UVURKHANGAI AIMAG

CHAPTER 3 BAYAN-UNDUR SUM, UVURKHANGAI AIMAG

3.1 Pilot Plant Site and Surrounding Condition

Bayan-Undur Sum of Arkhangai Aimag is located on the steppe area of Mongolia, north 46° 30' east 104° 07' and 300 km away from Ulaanbaatar. The population of Bayan-Undur Sum is 4,915. A pilot plant has been installed beside a hospital and supplies generated electricity to the hospital and school dormitory. The position of pilot plant equipment was planned to be in the protected area of a lightning rod. In addition, the position of the wind turbine was considered to avoid turbulence caused by obstacles such as buildings or trees in upwind. The position of the PV array was selected to be out of the shadow area of the wind turbine and other buildings. Photo II.3.1-1 shows the pilot plant in Bayan-Undur Sum and Figure II.3.1-1 shows the position of pilot plant equipment.

Photo II.3.1-1 Pilot Plant in Bayan-Undur Sum

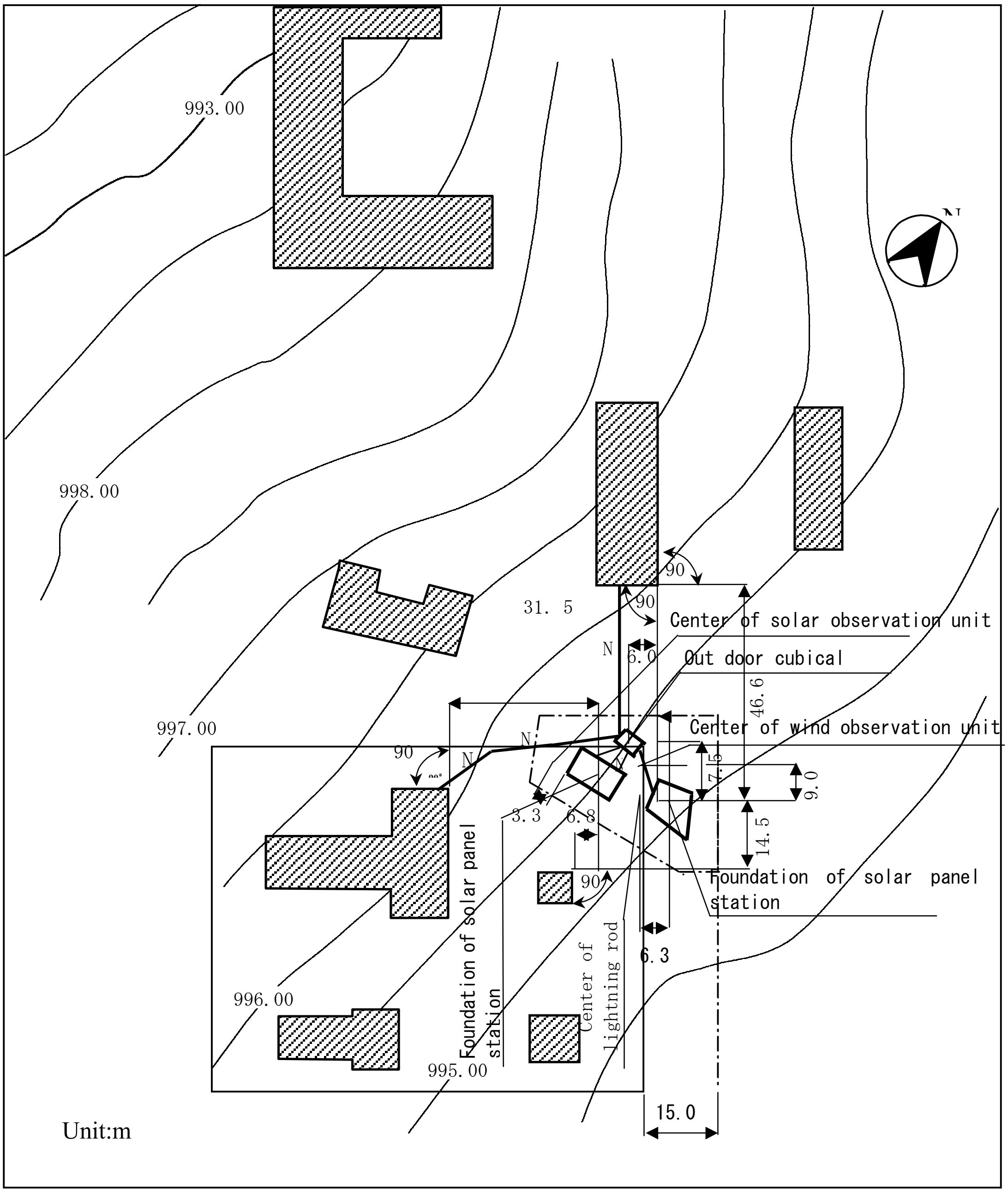

Figure II.3.1-1 Plot plan of pilot plant (Bayan-Undur)

3.2 Calculation of Generation Capacity and Power Output

3.2.1 PV power Generation

In Bayan-Undur Sum, power output by using PV system (installation angle is 65 degrees and 100 % output) was estimated on the basis of solar irradiation data at Bayankhongor, where the capital of Uvurkhangai Aimag is located, because the data are not available at Bayan-Undur Sum center. The solar irradiation data at the pilot plant has been collected since June 1999. Both solar irradiation data, from the Meteorological Department and pilot plant, are compared to clarify the difference. Table II.3.2-1 shows actual power output and estimated output of the PV system on the basis of solar irradiation data that was collected by Meteorological Department and pilot plant.

Table II.3.2-1 Power Generation by PV System Against Standard Generation and Comparison of Measured Average Global Solar Irradiation Level

Item	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Standard average global solar irradiation** (kWh／m²・day)	7.3	6.1	6.2	5.5	4.4	2.5	1.5	2.2	3.1	4.2	6.1	7.1
Estimated average generating power (kWh／day) (Calculation based on standard average global solar irradiation)	19.0	16.6	20.0	23.0	25.7	21.3	14.6	20.3	22.0	19.6	21.0	19.6
Actual measured average global solar irradiation*** (kWh／m²・day)	7.0*	6.5	5.5	4.0	3.5	2.1	1.5	1.8	3.0	4.3	5.2	5.9
Actual measured average generated power (kWh／day)	11.1	12.4	13.1	12.5	15.0	13.3	12.6	11.7	12.7	14.0	15.0	13.6
Estimated average generating power[1] (kWh／day) (Calculation based on measured average global solar irradiation)	17.5	16.9	16.9	16.2	19.9	16.5	13.5	15.2	19.9	20.6	17.6	16.2
Theoretically average generating power[2] (kWh／day) (Calculation based on measured average global solar irradiation)	14.9	14.3	14.3	13.8	16.9	14.0	11.5	12.9	16.9	17.2	15.0	13.7
Ratio of average global solar irradiation (Measured／Standard)	0.96	1.07	0.89	0.73	0.80	0.84	1.00	0.82	0.97	1.02	0.85	0.83

1 Estimated average generating power: Computed inclined solar irradiation on the base of global irradiation and multiplied by total array capacity。

2 Theoretical average generated power: On the base of measured global solar irradiation, average generation power is estimated considering deviation from Pmax point, dirtiness of surface of module, deterioration and so on

* An average data from 7th July (24 days)

** A standard average global solar irradiation is the data of Mongolian Meteorological Agency from 1988 to 1997 years (10 years average).

*** An actual average global solar irradiation is the data recorded at pilot plant site from July 1999 to June 2000.

From the above table, it could be understood that the difference in the ratio between standard and measured average global irradiation differs every month, where an actual measured value is smaller than the standard average global irradiation value except during the months of July and December of 1999 and March 2000. The amount of actual measured average power generation increases gradually after the establishment, and records the maximum value in October 1999 and April 2000. It is understood that except December the actual measured value of generated power shows a value closer to the theoretically computed power generating value. In December, as a storage battery reached the over discharge protection voltage, it stopped the system to prevent it automatically, due to which recording error was occurred. Possible causes of difference in the standard and the measured average global solar irradiation data, are a difference in the measurement years, a difference in the measurement point, possible recording error of the observation staff, yearly differences in the weather conditions and so on can be raised. In the case of generated and estimated generating power, theoretically even if a system has power generating ability, when the voltage of the storage battery reaches the over-charging prevention point or when a storage battery becomes fully charged and load isn’t used, it disconnects the PV array to protect the storage battery. Due to this possible reason, the amount of measured generated power is smaller than the amount of theoretically generated power.

3.2.2 Wind Power Generation

Power output from wind turbine is estimated based on the average wind speed by the Meteorological Department. The power output, which is estimated based on the wind data of the Meteorological Department and pilot plant, is compared. Rayleigh distribution, a kind of probability density function, was used for power output estimation from wind turbine. Table Ⅱ.3.2-2 shows the difference of actual and estimated power output on the basis of Meteorological Department data and pilot plant data.

Table II.3.2-2 Actual and Estimated Power Output on the Basis of Meteorological Department Data and Pilot Plant Data.

Bayan-Undur	1999 Jun	Jul	Aug	Sep	Oct	Nov	Dec	2000 Jan	Feb	Mar	Apr	May
Average wind speed (M/H department data) (m/s)[1]	2.6	2.1	1.9	2.8	2.2	3.2	3.1	2.3	2.5	2.7	3.7	4.7
Estimated power generation (M/H department data) (kWh/day)	0.9	0.1	-0.1	1.3	0.2	2.2	1.9	0.4	0.7	1.1	3.5	6.6
Average wind speed (Pilot Plant data) (m/s)[2]	5.1	3.9	4.3	4.6	4.1	4.2	4.1	4.3	4	4.8	6	5.6
Estimated power generation (Pilot Plant data) (kWh/day)	8.0	4.1	5.3	6.3	4.7	5.0	4.7	5.3	4.4	7.0	11.2	9.8
Actual power output (kWh/day)	3.3	2.9	3.4	4.5	2.6	0	3.3	3.8	1.7	2.8	5.1	5.9
Pilot Plant／M/H data	2.0	1.9	2.3	1.6	1.9	1.3	1.3	1.9	1.6	1.8	1.6	1.2

*1 Average data of Mongol Meteorological Agency is from year 1988 to 1997.

*2 Data of Pilot plant from June 1999 to May 2000.

Table II.3.2-2 indicates that the monitor of wind speed in Bayan-Undur has a tendency to read the wind speed small. The difference between actual power output and estimated power output is caused by the battery protection system of pilot plant. To protect storage batteries, the power is consumed by dump load when battery voltage reaches over charging prevention voltage or is fully full charged with no load. Therefore, the actual power output becomes smaller than that of estimated output.

3.3 Load of the Pilot Plant Facility

In Bayan-Undur Sum, generated electricity from the pilot plant is being supplied to a hospital and school dormitory because Bayan-Undur Sum requested the hospital and dormitory as pilot plant facilities. The main load of the pilot plant facilities is fluorescent lamps for operation and treatments at night. The other loads are DC input refrigerators, audiovisual equipment such as televisions and video decks. An electric kettle was supplied to the hospitals due to the necessity of a water heating system for emergency cases despite the high power consumption. Those loads are selected to have balance with power output in winter when power output estimation is lowest throughout the year. Table II.3.3-1 shows expected power output by PV-Wind hybrid system. Table II.3.3-2 shows load capacity and estimated power consumption.

Table II.3.3-1 Expected Power Generation from PV - Wind Hybrid System.

	Expected power generation from Wind turbine (kWh/day)	Expected power generation from PV array (kWh/day)	Total power generation (kWh/day)	Inverter output(1) (kWh/day)
Bayan-Undur	0.88	16.83	17.71	12.2

(1) DC refrigerator power consumption (1.56kWh/day) and)Inverter loss 80 %

Table II.3.3-2 Load Capacity and Estimated Power Consumption

Load	Load Capacity		Daily utilization (Winter)		Consumption Power (Wh)
	No.	W	Hours	Time period	
Lighting				5:00～9:00	
Room (hospital)	7	20	12	16:00～24:00	1,680
Corridor(hospital)	5	20	17	6:00～23:00	1,700
Dormitory	2	20	8	16:00～24:00	320
Dormitory	4	20	1 7	6:00～23:00	1,360
Toilet	2	25	5	--	250
Television	1	75	6	--	450
Video-deck	1	20	3	--	60
Electric kettle	1	2,000	3.4	--	6,800

Total 12,620 （Wh）

（Source ： JICA Study Team, Site survey）

3.4 Power Distribution Equipment and Electrical Wiring

3.4.1 Power Distribution Equipment

Power distribution equipment for the pilot plant was arranged in Mongolia. As an example, electrical lines that connected the PV array and wind turbine to the cubicle were settled underground. The cables are shown as follows.

- Wind turbine to Cubicle : 38mm^2, 3 core cable, single line
- PV array to Cubicle : 22mm^2, 3 core cable, double line

3.4.2 Electrical Wiring

Settled electrical new wires prevent accidents caused by existing old wires. Those wires were connected to only new provided electric equipment due to limited power output from the system.

Figure II.3.4-1 shows the internal electrical wiring of the pilot plant at Bayan-Undur Sum.

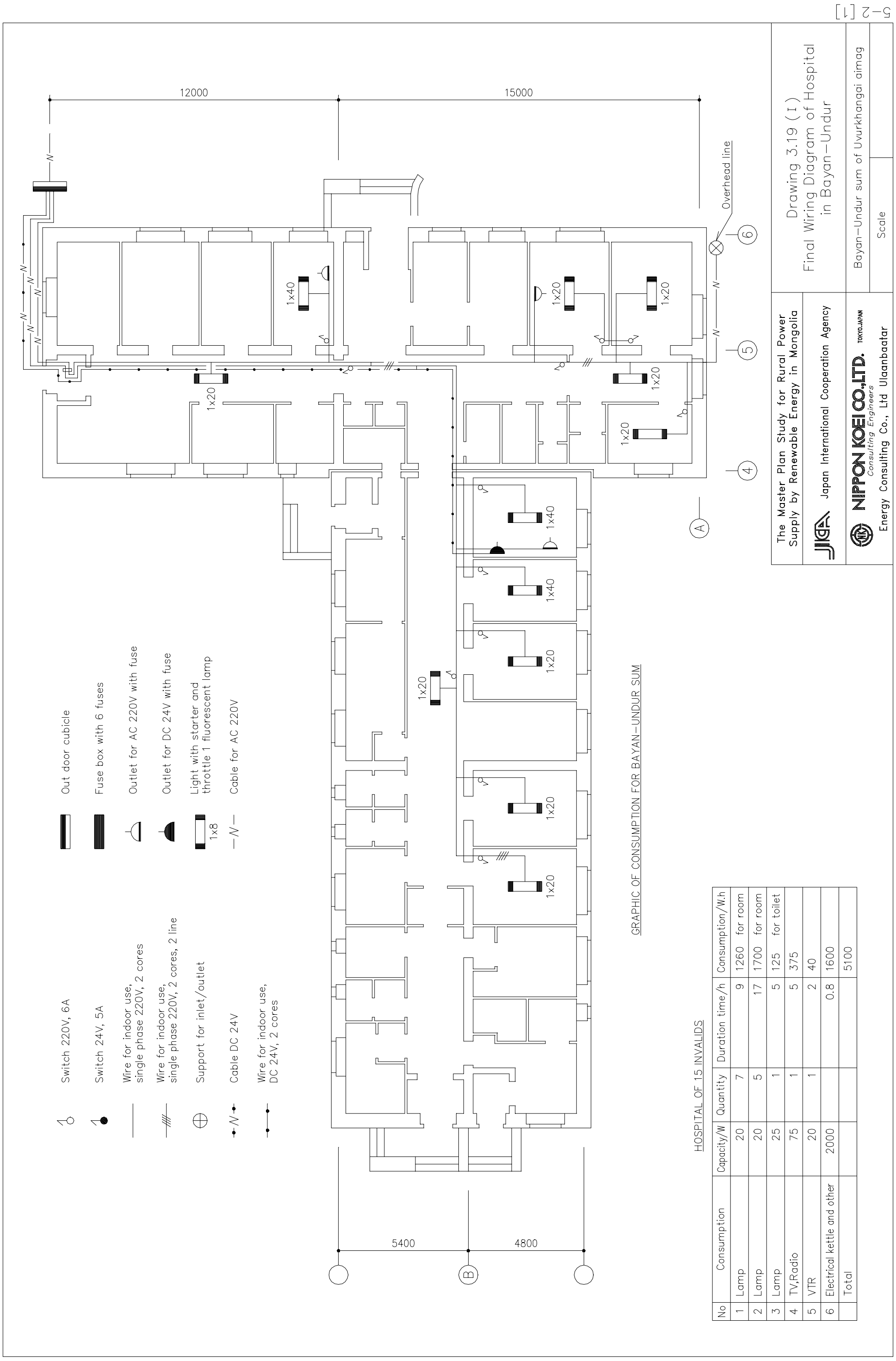

Figure II.3.4-1 Electrical Diagram of Bayan-Undur