OPERATION FREQUENCY OF THE SSPS/DCS

by

Belinda Wong Swanson
University of Arizona

ABSTRACT

Daily usage factors of the DCS subsystems were calculated to see how often the subsystems were operated during the time the radiation level was above 300 W/M**2. The frequency distribution of the subsystems' working hours on nonholidays were obtained to see their frequency and length of operation within a period.

INTRODUCTION

The function of a solar power plant is to produce electricity. However its productivity its limited by the environmental conditions and thermodynamic transients inherent in the process. It requires sufficient radiation, clear sky and low wind velocity. In addition, depending on the design of the system, there may be a long delay between the turn-on time of the collectors and the time when power is supplied to the utility grid. The frequency and duration of plant operation is one measure of the plant's effectiveness in performing its function.

This paper analyzes the effectiveness of the SSPS/Distributed Collector System (DCS). It uses the hours of operation (working hours) of the subsystems, i.e. single-axis tracking collector field, dual-axis tracking collector field, power conversion system, and hours of connection to the utility grid to find:

1) the daily and average daily usage factors,
2) the mean working hours, and
3) the frequency distribution of the working hours

at each stage of the plant. The usage factors show the percentage of the subsystems' operation time with respect to the hours with sufficient radiation (above 300 W/M**2) to operate the collectors. The mean working hours show the average daily operating time for each subsystem. The frequency distributions tell how often and for how long the subsystems operate.

PROCEDURE

Daily usage factors (duf) for the subsystems were obtained for two types of days:

1) Normal operating days__days on which the average radiation is above 300 W/M**2, there are more than 3 hours of radiation above 600 W/M**2, there is no high wind velocity to interrupt collector operation, and there is operation of at least the collector field.
2) Good operating days__same environmental conditions

as above but with operation of the entire system.

The equations for the daily usage factor and average daily usage factor have been discussed in detail in section 3.3 of Ref. 1, therefore they will not be given here.

Working hours from all nonholidays in the analysis period are used to find the mean working hours and the variance for each subsystem. The equations are:

$$\text{MEAN} = \frac{1}{n}\left(\sum_{i}^{n} X_i\right) = \bar{X}$$

$$\text{VARIANCE} = \frac{\sum_{i}^{n}\left[(X_i - \bar{X})^2\right]}{n - 1} .$$

For the working hour frequency distribution, the working hours are divided into 14 intervals. The first interval is for days which had operating hours greater or equal to 0 and less than 1, the second interval greater or equal to 1 and less than 2, until the last interval for 13 or more operating hours. The number of occurrences or observations (days in this case) in each interval is obtained and is divided by the total number of working days (nonholidays) in the period to find the frequency distribution of the working hours. The number of observations up to each interval are summed up to find the corresponding cumulative value, and divided by the total working days to obtain the cumulative probability.

RESULTS

Average and Daily Average Usage Factors

The daily usage factors and average daily usage factors for the subsystems of single-axis tracking collector field (1-AXIS), dual-axis tracking collector field (2-AXIS), power conversion system (PCS) and power to the grid (GRID) were calculated for two analysis periods--January through April and May through August of 1984--and for two types of operating day.

Table 1 shows the results from the normal operating day analysis. There were altogether 52 normal operating days in the first period and 58 in the second period. Of these, the 1-AXIS system worked for 52 days in period 1 and 56 days in period 2; the 2-AXIS system worked 43 days and 55 days respectively; the PCS 38 and 46 respectively; the GRID 35 and 46 respectively.

Note that there are daily usage factors with values greater than 1.0. This may be that the subsystem operated longer than there were hours of sufficient radiation, or that there were frequent cloud passages.

There were three days during the first period (13 Jan., 20 Feb., 8 Mar.) when the PCS had longer operating hours than those of either collector fields, resulting in higher dufs. On each occassion, the PCS had been out of service for repair the previous days while the collector fields continued to function. Consequently the storage tank became fully charged. When the PCS resumed operation, it had to start working before the collector fields in order to discharge the storage tank.

Table 2 shows the results from the good operating day analysis. Recall these were days of good environmental conditions and that all subsystems had functioned. There were 30 such days in the first period and 43 in the second. Table 3 compares the average daily usage factors of Tables 1 and 2. It could be seen that the duf values on good operating days are slightly higher than those on normal operating days. For those days that the PCS did not function, the collector fields operating time would be limited by the temperature of the storage tank since it is not being discharged. The results show that on those days when there were favourable conditions to operate the DCS, on the average the single-axis system worked for about 90% of the operable hours, the dual-axis 94%, the PCS 50% and the grid 35%.

Working Hour Frequency Distributions

The mean working hours and the working hour frequency distributions of the subsystems and of grid connection on nonholidays are tabulated and plotted in Figures 1 to 4. Figure 5 is the statistics for the operables hours. The analysis period is January to August 1984.

The single-axis system worked 5.13 hours per day on the average, with 37 days or 24% of the total working days with less than 1 hour of operation per day. Excluding the first interval, the most frequently occurred interval is between 7 and 8 hours, with 35 days or 22% of the total working days. It never worked more than ten hours daily.

The dual-axis system averaged 5.48 hours of operation a day. There were 42 days (27% of the total working days) that it worked for 1 hour or less. It has a rather uniform work-hour distribution, with only 15 days (10%) in the peak interval of 8 to 9 working hours. There were 7 days that had between 12 and 13 hours of operation.

The power conversion system averaged 2.39 working hours a day. It operated for less than 1 hour on 72 (46%) of the working days. The peak interval is between 3 and 4 hours with 19 working days (12%). There was 1 day that it worked between 10 to 11 hours.

There was 1.77 hours of grid synchronization a day on the average, 77 (49%) of the working days had less than 1 hour of power supply to the grid. The peak occurs between hours 1 and 3, with 38 (24%) working days falling in these two intervals. There was 1 day when power was supplied to the grid for 9 to 10 hours.

During the first eight months of 1984, the average daily hours with radiation above 300 W/M**2 was 7.39. Fourteen (9%) working days had less than 1 hour of operable radiation; twenty-one (13%) had between 9 to 10 hours, which was the most frequent interval. There was 1 day with over 13 hours of radiation above 300 W/M**2.

Cumulative Distributions

The cumulative distributions of the subsystems working hours and of the operable hours are shown in Figure 6. It could be seen that 51% of the total working days had 1 or more hours of power supply to the grid; 41% had between 1 to 5 hours and 10% between 5 and 10 hours. The PCS had 1 or more hour of operation 54% of the total working days; it worked for 1 to 3 hours 15% of the time, 3 to 7 hours about 35% of the time and between 7 to 10 hours per day 4% of the time. The dual-axis collector system had at least 1 working hour 73% of the total working days; 10% was between 1 and 4 hours, 61% between 4 and 11 hours, and 2% between 11 and 13 hours of operation per day. The single-axis tracking collector system worked at least one hour 76% of the total working days; 16% was between 1 and 5 hours, 40% between 5 and 9 hours, and 20% between 9 and 10 hours.

There was at least one hour of operable radiation 91% of the total working days; 21% had between 1 and 6 hours, 55% between 6 and 11 hours, and 15% between 11 and 14 hours. Thus most of the working days had around 6 to 11 hours of radiation above 300 W/M**2, with the collector fields working between 4 to 10 hours daily. In general the PCS worked for 3 to 7 hours per day, and power was supplied to the grid between 1 and 5 hours.

The energy production for the first eight months of 1984 amounts to 360.56 MWH for the single-axis tracking collector field and 288.70 MWH for the dual-axis tracking collector field. This shows that the single-axis collectors are more effective: they produced more energy while requiring less operating time.

CONCLUSIONS

Daily usage factors and frequency distributions of the Distributed Collector System were obtained to see the frequency and length of subsystems' operation and of power supply to the utility grid during the first eight months of 1984. The general conclusions are:

1) From the duf analysis, it was observed that while there were occassions when the collectors worked for longer hours than there were hours of radiation above 300 W/M**2 (operable hours), they did not occur frequently. This indicates that the collectors usually stopped operation before the radiation level has been reduced to 300 W/M**2.

2) The single-axis tracking collectors worked for 90% and the dual-axis tracking collectors 94% of the operable hours. The power conversion system worked for about 50% and there was power to the grid 35% of the operable hours.

3) The working hour frequency distribution analysis found that there was 7.4 hours of operable radiation per day on the average, with the dual-axis system working for 5.5 hours and the single-axis system for 5 hours. The power conversion system averaged 2.4 hours of daily operation while power was supplied to the utility grid about 1.8 hours per day.

4) A majority of the working days had from 6 to 11 hours of operable radiation; the single-axis tracking collectors worked between 5 and 10 hours daily, the dual-axis collectors between 4 and 11 hours daily for most of the working days. The power conversion system usually operated for 3 to 7 hours per day, with power being supplied to the grid 1 to 5 hours a day.

5) The single-axis tracking collectors have operated more effectively than the dual-axis collectors in the first eight months of 1984. The single-axis system had higher energy production but required less daily working hours.

REFERENCE

1) "Maintenance, Reliability, Availability", B.W. Swanson and R. Fazzolare, IEA/SSPS Distributed Collector System Deliverable Review. Tabernas, October 1984.

ACKNOWLEDGEMENTS

I would like to thank Juan Ramos of Cia. Sevillana for his invaluable support and advice on this study.

TABLE 1: DCS Subsystems Usage Factors For Normal Operating Days

1ST PERIOD '84

DAILY USAGE FACTORS FOR:

		1-AXIS	2-AXIS	PCS	GRID
40184	1.	0.823	0.809	0.206	0.000
50184	2.	1.000	0.955	0.576	0.409
100184	3.	0.994	0.951	0.477	0.300
110184	4.	0.546	0.507	0.000	0.000
130184	5.	0.684	0.669	0.788	0.570
160184	6.	0.977	0.986	0.489	0.306
170184	7.	0.901	0.918	0.489	0.369
180184	8.	1.008	1.015	0.579	0.448
240184	9.	0.666	0.000	0.000	0.000
250184	10.	0.971	0.929	0.551	0.313
260184	11.	1.136	1.020	0.000	0.000
270184	12.	0.692	0.653	0.470	0.205
300184	13.	0.947	0.985	0.480	0.297
310184	14.	0.944	0.897	0.636	0.313
10284	15.	0.938	0.972	0.505	0.382
60284	16.	0.907	0.962	0.387	0.174
70284	17.	0.914	0.995	0.321	0.189
80284	18.	0.913	0.806	0.431	0.295
90284	19.	0.973	0.991	0.488	0.355
100284	20.	0.849	0.951	0.513	0.422
130284	21.	1.055	1.081	0.000	0.000
200284	22.	0.451	0.444	0.480	0.301
210284	23.	0.740	0.449	0.000	0.000
240284	24.	1.151	0.000	0.000	0.000
290284	25.	0.817	0.932	0.000	0.000
10384	26.	0.906	1.133	0.461	0.270
20384	27.	0.595	0.625	0.074	0.000
60384	28.	0.593	0.000	0.000	0.000
70384	29.	0.313	0.000	0.000	0.000
80384	30.	0.751	0.837	0.875	0.732
90384	31.	0.996	1.089	0.659	0.516
120384	32.	0.697	0.912	0.579	0.449
140384	33.	0.870	0.983	0.617	0.495
150384	34.	1.141	1.246	0.000	0.000
160384	35.	1.018	0.981	0.544	0.349
230384	36.	0.582	0.794	0.000	0.000
260384	37.	0.734	0.000	0.600	0.495
270384	38.	0.721	0.000	0.464	0.381
280384	39.	0.490	0.000	0.246	0.123
290384	40.	1.006	0.000	0.526	0.404
300384	41.	0.749	0.000	0.519	0.432
40484	42.	0.746	0.819	0.635	0.579
50484	43.	1.153	1.147	0.547	0.409
60484	44.	0.716	0.888	0.731	0.645
110484	45.	0.824	0.918	0.637	0.534
130484	46.	1.218	1.333	0.381	0.216
160484	47.	1.005	1.011	0.000	0.000
170484	48.	0.938	1.062	0.142	0.000
180484	49.	0.692	0.828	0.489	0.347
260484	50.	0.476	0.514	0.000	0.000
270484	51.	0.874	0.996	0.000	0.000
300484	52.	1.022	1.083	0.485	0.276

AVERAGE USAGE FACTOR/DAYS CONSIDERED FOR
1-AXIS = 0.843/52.; 2-AXIS = 0.909/43.
PCS = 0.502/38.; GRID = 0.380/35.

2ND PERIOD '84

DAILY USAGE FACTORS FOR:

		1-AXIS	2-AXIS	PCS	GRID
30584	1.	0.936	0.000	0.368	0.211
40584	2.	1.020	1.141	0.484	0.386
110584	3.	1.112	1.295	0.000	0.000
140584	4.	0.661	0.526	0.000	0.000
150584	5.	0.870	1.086	0.692	0.586
180584	6.	1.014	0.966	0.609	0.417
210584	7.	0.820	1.008	0.519	0.423
220584	8.	0.733	0.867	0.655	0.597
230584	9.	0.743	0.922	0.677	0.617
240584	10.	0.709	0.776	0.585	0.503
250584	11.	1.181	1.305	0.327	0.174
280584	12.	0.430	0.520	0.000	0.000
310584	13.	0.903	0.846	0.541	0.374
40684	14.	0.846	1.045	0.826	0.721
60684	15.	0.734	0.923	0.532	0.461
70684	16.	0.834	1.056	0.921	0.847
80684	17.	0.000	0.696	0.342	0.241
110684	18.	0.886	0.969	0.498	0.389
120684	19.	0.857	0.988	0.460	0.389
130684	20.	0.843	0.963	0.546	0.462
140684	21.	0.800	0.907	0.506	0.425
150684	22.	0.820	0.937	0.582	0.504
190684	23.	0.594	0.745	0.000	0.000
200684	24.	0.750	0.759	0.288	0.172
20784	25.	0.782	0.771	0.291	0.189
30784	26.	0.825	0.839	0.246	0.131
40784	27.	0.768	0.980	0.424	0.330
50784	28.	0.776	1.036	0.542	0.448
60784	29.	0.789	1.047	0.551	0.456
90784	30.	0.840	1.082	0.371	0.203
100784	31.	0.940	1.048	0.000	0.000
110784	32.	0.818	0.886	0.256	0.172
120784	33.	0.763	0.935	0.487	0.403
130784	34.	0.934	1.086	0.340	0.237
160784	35.	0.666	0.782	0.000	0.000
170784	36.	0.000	0.845	0.295	0.154
180784	37.	0.543	0.577	0.351	0.163
190784	38.	0.842	0.882	0.307	0.170
200784	39.	0.789	0.959	0.379	0.261
230784	40.	1.041	1.122	0.000	0.000
240784	41.	0.973	0.898	0.294	0.142
260784	42.	0.996	0.979	0.000	0.000
270784	43.	0.729	0.821	0.244	0.105
300784	44.	0.819	1.033	0.364	0.262
310784	45.	0.895	1.138	0.510	0.419
10884	46.	0.537	0.635	0.284	0.138
20884	47.	0.740	1.002	0.570	0.493
30884	48.	0.858	0.912	0.344	0.243
60884	49.	0.575	0.655	0.000	0.000
70884	50.	0.847	0.978	0.401	0.319
80884	51.	0.714	0.843	0.385	0.282
100884	52.	0.839	0.965	0.000	0.000
130884	53.	0.662	0.913	0.341	0.176
160884	54.	0.806	0.000	0.000	0.000
280884	55.	0.750	0.000	0.000	0.000
290884	56.	0.740	0.938	0.348	0.223
300884	57.	0.779	0.969	0.313	0.229
310884	58.	0.755	0.908	0.271	0.194

AVERAGE USAGE FACTOR/DAYS CONSIDERED FOR:
1-AXIS = 0.808/56.; 2-AXIS = 0.922/55.
PCS = 0.445/46.; GRID = 0.336/46.

TABLE 2: DCS Subsystems Usage Factors for Good Operating Days

GOOD OPERATING DAYS, 1ST PERIOD '84

DAILY USAGE FACTORS FOR:

		1-AXIS	2-AXIS	PCS	GRID
50184	1.	1.000	0.955	0.576	0.409
100184	2.	0.994	0.951	0.477	0.300
130184	3.	0.684	0.669	0.788	0.570
160184	4.	0.977	0.986	0.489	0.306
170184	5.	0.901	0.918	0.489	0.369
180184	6.	1.008	1.015	0.579	0.448
250184	7.	0.971	0.929	0.551	0.313
270184	8.	0.692	0.653	0.470	0.205
300184	9.	0.947	0.985	0.480	0.297
310184	10.	0.944	0.897	0.636	0.313
10284	11.	0.938	0.972	0.505	0.382
60284	12.	0.937	0.962	0.387	0.174
70284	13.	0.914	0.995	0.321	0.189
80284	14.	0.913	0.806	0.431	0.295
90284	15.	0.973	0.991	0.488	0.355
100284	16.	0.849	0.951	0.513	0.422
200284	17.	0.451	0.444	0.480	0.301
10384	18.	0.906	1.133	0.461	0.270
80384	19.	0.751	0.837	0.875	0.732
90384	20.	0.996	1.089	0.659	0.516
120384	21.	0.697	0.912	0.579	0.449
140384	22.	0.870	0.983	0.617	0.495
160384	23.	1.018	0.981	0.544	0.349
40484	24.	0.746	0.819	0.635	0.579
50484	25.	1.153	1.147	0.547	0.409
60484	26.	0.716	0.888	0.731	0.645
110484	27.	0.824	0.918	0.637	0.534
130484	28.	1.218	1.333	0.381	0.216
180484	29.	0.692	0.828	0.489	0.347
300484	30.	1.022	1.083	0.485	0.276

AVERAGE USAGE FACTOR:
1-AXIS = 0.890; 2-AXIS = 0.934
PCS = 0.543; GRID = 0.382

GOOD OPERATING DAYS, 2ND PERIOD '84

DAILY USAGE FACTORS FOR:

		1-AXIS	2-AXIS	PCS	GRID
40584	1.	1.020	1.141	0.484	0.386
150584	2.	0.870	1.086	0.692	0.586
180584	3.	1.014	0.966	0.609	0.417
210584	4.	0.820	1.008	0.519	0.423
220584	5.	0.733	0.867	0.655	0.597
230584	6.	0.743	0.922	0.677	0.617
240584	7.	0.709	0.776	0.585	0.503
250584	8.	1.181	1.305	0.327	0.174
310584	9.	0.903	0.846	0.541	0.374
40684	10.	0.846	1.045	0.826	0.721
60684	11.	0.734	0.923	0.532	0.461
70684	12.	0.834	1.056	0.921	0.847
110684	13.	0.886	0.969	0.498	0.389
120684	14.	0.857	0.988	0.460	0.389
130684	15.	0.843	0.963	0.546	0.462
140684	16.	0.800	0.907	0.506	0.425
150684	17.	0.820	0.937	0.582	0.504
200684	18.	0.750	0.759	0.288	0.172
20784	19.	0.782	0.771	0.291	0.189
30784	20.	0.825	0.839	0.246	0.131
40784	21.	0.768	0.980	0.424	0.330
50784	22.	0.776	1.036	0.542	0.448
60784	23.	0.789	1.047	0.551	0.456
90784	24.	0.840	1.082	0.371	0.203
110784	25.	0.818	0.886	0.256	0.172
120784	26.	0.763	0.935	0.487	0.403
130784	27.	0.934	1.086	0.340	0.237
180784	28.	0.543	0.577	0.351	0.163
190784	29.	0.842	0.882	0.307	0.170
200784	30.	0.789	0.959	0.379	0.261
240784	31.	0.973	0.898	0.294	0.142
270784	32.	0.729	0.821	0.244	0.105
300784	33.	0.819	1.033	0.364	0.262
310784	34.	0.895	1.138	0.510	0.419
10884	35.	0.537	0.635	0.284	0.138
20884	36.	0.740	1.002	0.570	0.493
30884	37.	0.858	0.912	0.344	0.243
70884	38.	0.847	0.978	0.401	0.319
80584	39.	0.714	0.843	0.385	0.282
130884	40.	0.662	0.913	0.341	0.176
290884	41.	0.740	0.938	0.348	0.223
300884	42.	0.779	0.969	0.313	0.229
310884	43.	0.755	0.908	0.271	0.194

AVERAGE USAGE FACTOR:
1-AXIS = 0.811; 2-AXIS = 0.943
PCS = 0.453; GRID = 0.345

Table 3: Average daily usage factors on normal and good operating days in 1984.

	January - April		May - August	
Subsystem	Normal	Good	Normal	Good
1-AXIS	0.843	0.890	0.808	0.811
2-AXIS	0.909	0.934	0.922	0.943
PCS	0.502	0.543	0.445	0.453
GRID	0.380	0.382	0.336	0.345

SINGLE-AXIS COLLECTOR FIELD

INTERVAL	OBS.	f(X)	F(X)
0<X< 1	37.	0.2372	0.2372
1<X< 2	3.	0.0192	0.2564
2<X< 3	5.	0.0321	0.2885
3<X< 4	6.	0.0385	0.3269
4<X< 5	12.	0.0769	0.4038
5<X< 6	14.	0.0897	0.4936
6<X< 7	10.	0.0641	0.5577
7<X< 8	35.	0.2244	0.7821
8<X< 9	18.	0.1154	0.8974
9<X<10	16.	0.1026	1.0000
10<X<11	0.	0.0000	1.0000
11<X<12	0.	0.0000	1.0000
12<X<13	0.	0.0000	1.0000
13<X	0.	0.0000	1.0000

MEAN = 5.13; VARIANCE = 11.31

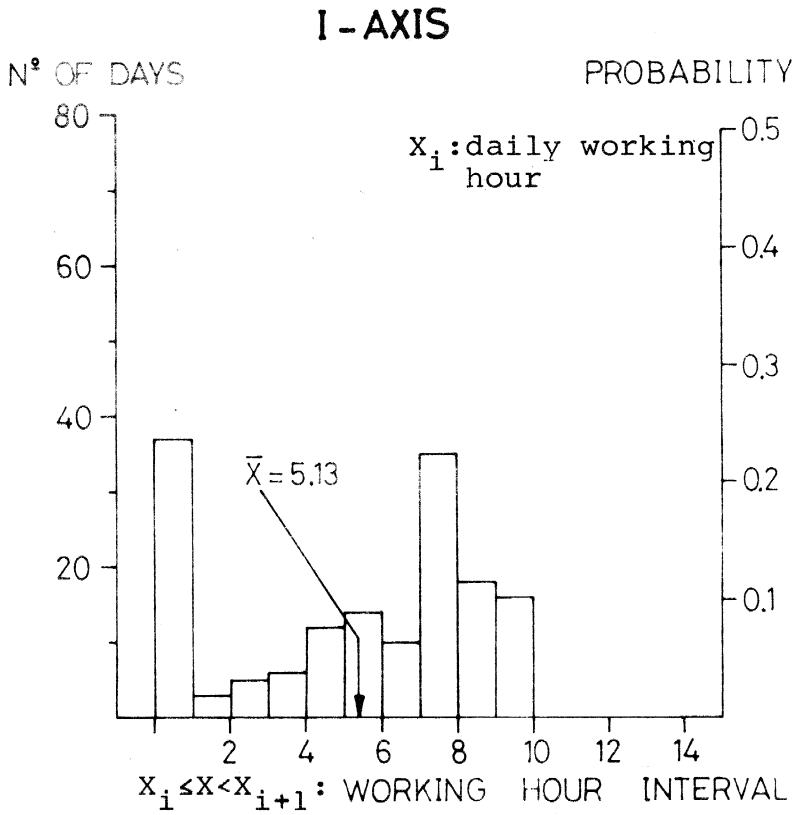

Figure 1: Single-axis tracking collector field daily working hour frequency distribution table and histogram. 'OBS' number of occurrences (days) in each interval. 'f(X)' probability of ocurrence in the interval. 'F(X)' cumulative probability up to the interval.

DUAL-AXIS COLLECTOR FIELD

INTERVAL	OBS.	f(X)	F(X)
0<X< 1	42.	0.2692	0.2692
1<X< 2	7.	0.0449	0.3141
2<X< 3	2.	0.0128	0.3269
3<X< 4	9.	0.0577	0.3846
4<X< 5	5.	0.0321	0.4167
5<X< 6	11.	0.0705	0.4872
6<X< 7	14.	0.0897	0.5769
7<X< 8	12.	0.0769	0.6538
8<X< 9	15.	0.0962	0.7500
9<X<10	11.	0.0705	0.8205
10<X<11	13.	0.0833	0.9038
11<X<12	8.	0.0513	0.9551
12<X<13	7.	0.0449	1.0000
13<X	0.	0.0000	1.0000

MEAN = 5.48; VARIANCE = 17.66

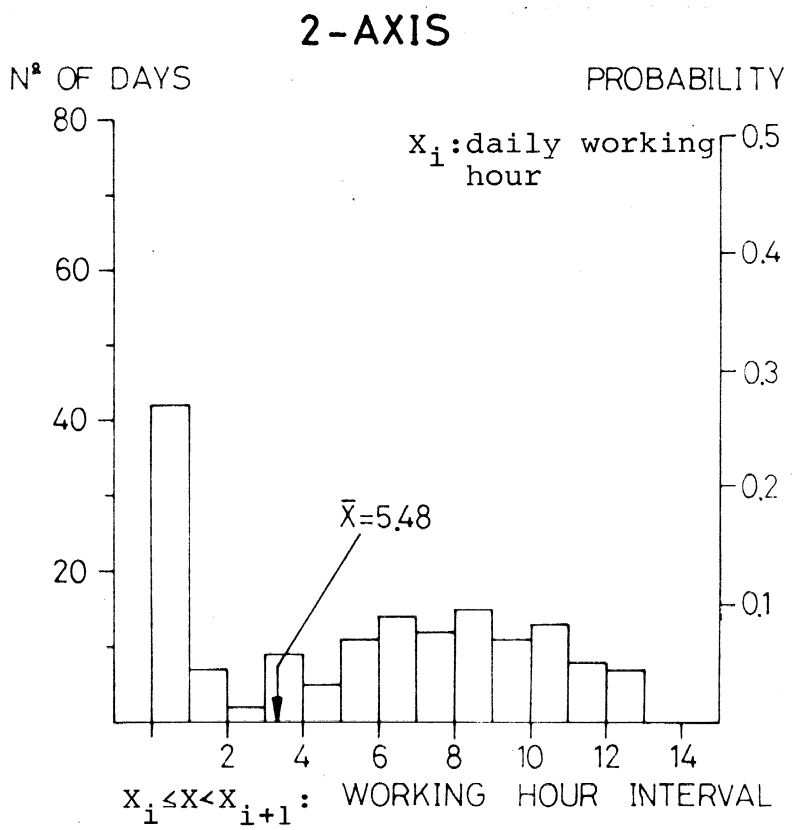

Figure 2: Dual-axis tracking collector field daily working hour frequency distribution table and histogram. 'OBS' number of occurrences (days) in each interval. 'f(X)' probability of occurrence in the interval. 'F(X)' cumulative probability up to the interval

PCS

INTERVAL	OBS.	f(X)	F(X)
0<X< 1	72.	0.4615	0.4615
1<X< 2	4.	0.0256	0.4872
2<X< 3	18.	0.1154	0.6026
3<X< 4	19.	0.1218	0.7244
4<X< 5	15.	0.0962	0.8205
5<X< 6	10.	0.0641	0.8846
6<X< 7	9.	0.0577	0.9423
7<X< 8	4.	0.0256	0.9679
8<X< 9	4.	0.0256	0.9936
9<X<10	0.	0.0000	0.9936
10<X<11	1.	0.0064	1.0000
11<X<12	0.	0.0000	1.0000
12<X<13	0.	0.0000	1.0000
13<X	0.	0.0000	1.0000

MEAN = 2.39; VARIANCE = 6.79

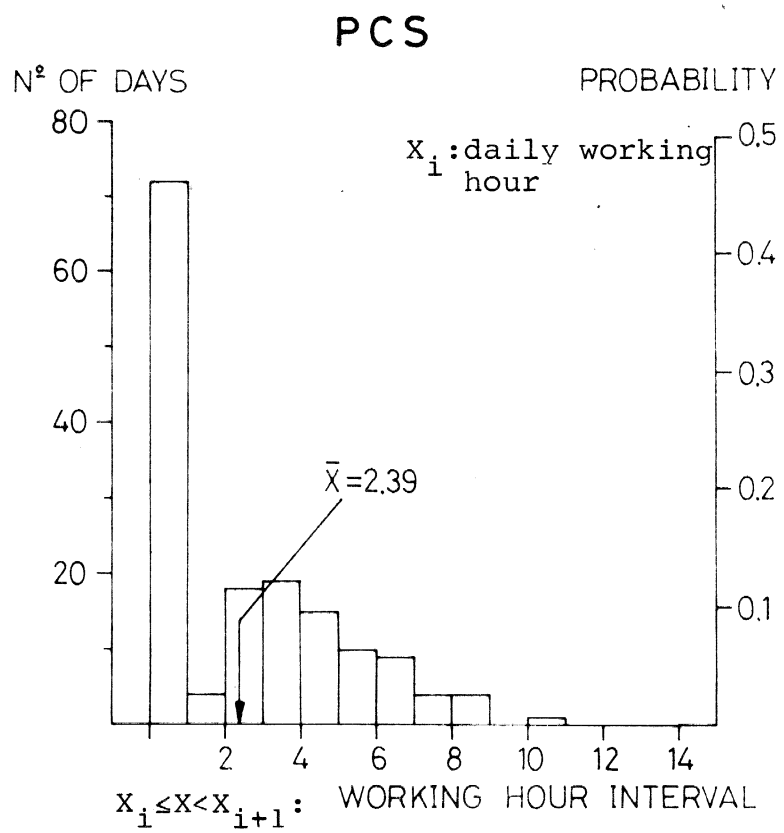

Figure 3: Power conversion system daily working hour frequency distribution table and histogram. 'OBS' number of occurrences (days) in each interval. 'f(X)' probability of occurrence in the interval. 'F(X)' cumulative probability up to the interval.

GRID

INTERVAL	OBS.	f(X)	F(X)
0<X< 1	77.	0.4936	0.4936
1<X< 2	19.	0.1218	0.6154
2<X< 3	19.	0.1218	0.7372
3<X< 4	13.	0.0833	0.8205
4<X< 5	12.	0.0769	0.8974
5<X< 6	7.	0.0449	0.9423
6<X< 7	4.	0.0256	0.9679
7<X< 8	3.	0.0192	0.9872
8<X< 9	1.	0.0064	0.9936
9<X<10	1.	0.0064	1.0000
10<X<11	0.	0.0000	1.0000
11<X<12	0.	0.0000	1.0000
12<X<13	0.	0.0000	1.0000
13<X	0	0.0000	1.0000

MEAN = 1.77 VARIANCE = 4.81

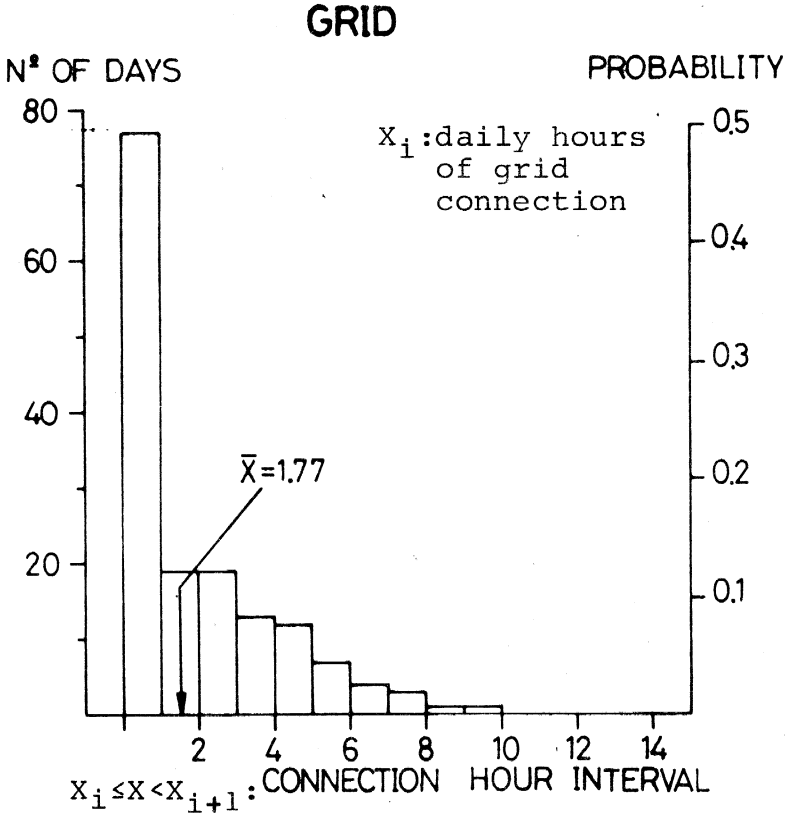

Figure 4: Daily grid connection hour frequency distribution table and histogram. 'OBS'_number of occurrences (days) in each interval. 'f(X)'_probability of occurrence in the interval. 'F(X)'_cumulative probability up to the interval.

HOURS OF RADIATION>300 W/M**2

INTERVAL	OBS.	f(X)	F(X)
0<X< 1	14.	0.0897	0.0897
1<X< 2	5.	0.0321	0.1218
2<X< 3	3.	0.0192	0.1410
3<X< 4	4.	0.0256	0.1667
4<X< 5	11.	0.0705	0.2372
5<X< 6	11.	0.0705	0.3077
6<X< 7	11.	0.0705	0.3782
7<X< 8	18.	0.1154	0.4936
8<X< 9	17.	0.1090	0.6026
9<X<10	21.	0.1346	0.7372
10<X<11	18.	0.1154	0.8526
11<X<12	16.	0.1026	0.9551
12<X<13	6.	0.0385	0.9936
13<X	1.	0.0064	1.0000

MEAN = 7.39; VARIANCE = 12.44

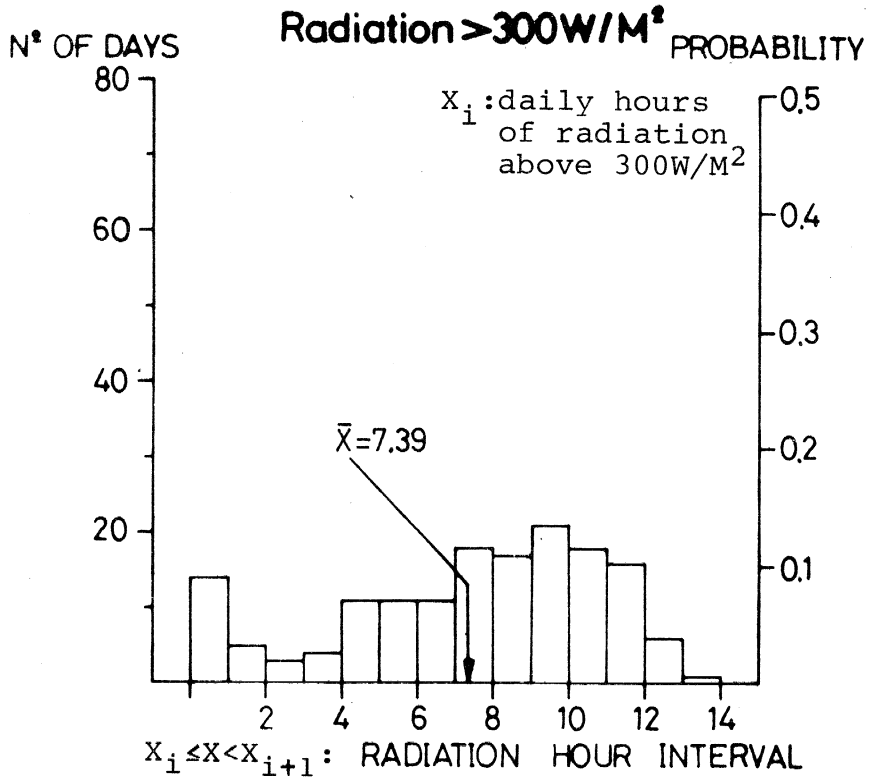

Figure 5: Daily hours of radiation 300W/M^2 frequency distribution table and histogram. 'OBS'_number of occurrences (days) in each interval. 'f(X)'_probability of occurrence in the interval. 'F(X)'_cumulative probability up to the interval.

FIGURE 6

RADIATION AND WORKING HOUR

CUMULATIVE DISTRIBUTION