CHAPTER IV

RESULTS AND DISCUSSION

1. Experiment 1 Analysis of Variance of the Output Voltage.

The output voltage in this experiment is the light energy, which receives from the sensor. The voltage outputs from experiment are different values because of many factors in experiment, for example in the morning the light energy is lower than the light energy form daylight.

In the first experiment, determining whether the different of times affects the output voltage or not. The experiment begins with running a completely randomized experiment with 6 level of different of interval times (10.00-11.00, 11.00-12.00, 12.00-13.00, 13.00-14.00, 14.00-15.00, 15.00-16.00) and 360 replicates. This experiment is run in random order.

The output voltage from the different of interval time in the first experiment can be plot, dot plot, to illustrate the means output voltage from the different of interval time are shown in figure 20.

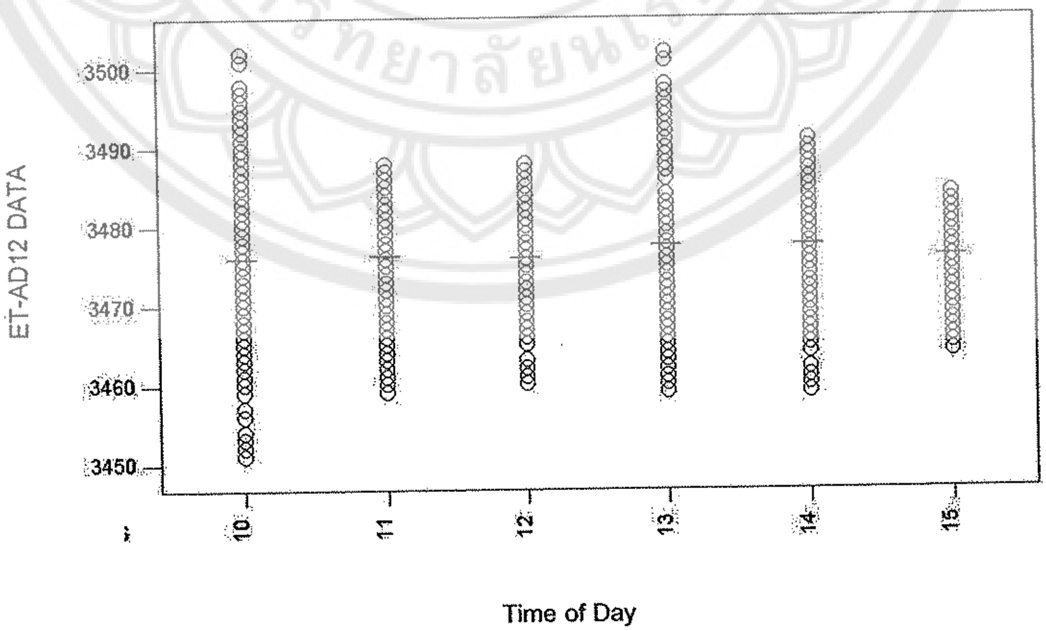

Figure 20 Dot Plot of ET-AD12 DATA by Time of Day

Analysis of Variance

Hypothesis in the experiment are;

H_0: $\mu_{10} = \mu_{11} = \mu_{12} = \mu_{13} = \mu_{14} = \mu_{15}$

H_1: $\mu_i \neq \mu_j$ At least one pair.

where μ_i = the means of voltage output at interval time i

when i = interval time at 10, 11, 12, 13, 14, 15 am.

Using the analysis of variance to test the null hypothesis (H_0) against the alternative hypothesis (H_1), these calculations would be performed on a computer, using a MINITAB program to analyze data from design experiment.

Table 5 Analysis of variance for the outputs voltage.

Source	df	SS	MS	F	P
Hours	5	648.9	129.8	2.09	0.064
Error	1334	82753.9	62		
Total	1339	83402.8			

Table 6 Number, Mean and Standard output of output voltage.

Level	N	Mean	St. Dev
10	360	3475.93	10.75
11	360	3476.32	6.27
12	360	3476.01	5.97
13	360	3477.47	9.78
14	360	3477.50	6.04
15	360	3475.99	4.93

The analysis of variance is summarized in table 5 Note that the between-treatment mean square (129.8) is many times larger than the within-treatment or error mean square (62.0). This indicates that it is unlikely that the treatment mean are equal. Table 5 shows that the *P* value is bigger than 0.05 (experimenter has selected $\alpha = 0.05$), the upper bound for the *P*-value is 0.05; that is, *P* =0.064 more than 0.05, then accept H_0 and conclude that the data output from different time not differ at α = 0.05

2. Experiment 2 Determining Optimum Parameter for GA

Determine optimum value for each parameter that effect with GA. Those consist of Population Size (*Pop*), Probability Mutation (*Pm*), and Probability Crossover (*Pc*).

There are three factors under study, and each factor is at three levels arranged in a factorial experiment; as follow.

1. Population Size (*Pop*), can divide into three levels by fundamental statistic are as follow 10, 30 and 50.
2. Probability Crossover (*Pc*) in this experiment separated into three levels are 0.1, 0.5 and 0.9.
3. Probability Mutation (*Pm*), as same as Pc, are 0.1, 0.5 and 0.9.

From the experiment will have resulted as follows table 7.

Table 7 Voltage Output from the Experiment 2.

No. test	Pop	Pc	Pm	Replicate	Mean	Max
1	10	0.1	0.1	1	2959.19	3103
2	10	0.1	0.1	2	3081.34	3364
3	10	0.1	0.5	1	3052.89	3285
4	10	0.1	0.5	2	3017.2	3238
5	10	0.1	0.9	1	3079.7	3332
6	10	0.1	0.9	2	3066.34	3348
7	10	0.5	0.1	1	3094.99	3411
8	10	0.5	0.1	2	2977.53	3090
9	10	0.5	0.5	1	3117.3	3361
10	10	0.5	0.5	2	3076.38	3267
11	10	0.5	0.9	1	3065.25	3266
12	10	0.5	0.9	2	3003.87	3274
13	10	0.9	0.1	1	3170.4	3323

Table 7 (Cont.)

No. test	Pop	Pc	Pm	Replicate	Mean	Max
14	10	0.9	0.1	2	3133.96	3458
15	10	0.9	0.5	1	3063.46	3271
16	10	0.9	0.5	2	3086.79	3401
17	10	0.9	0.9	1	3118.67	3413
18	10	0.9	0.9	2	3036.87	3296
19	30	0.1	0.1	1	3095.55	3350
20	30	0.1	0.1	2	3090.9	3448
21	30	0.1	0.5	1	3063.22	3453
22	30	0.1	0.5	2	3079.33	3450
23	30	0.1	0.9	1	3055.68	3364
24	30	0.1	0.9	2	3131.21	3377
25	30	0.5	0.1	1	3141.11	3492
26	30	0.5	0.1	2	3123.18	3336
27	30	0.5	0.5	1	3147.1	3491
28	30	0.5	0.5	2	3104.9	3418
29	30	0.5	0.9	1	3055.8	3371
30	30	0.5	0.9	2	3050.17	3347
31	30	0.9	0.1	1	3130.54	3371
32	30	0.9	0.1	2	3093.06	3354
33	30	0.9	0.5	1	3191.53	3456
34	30	0.9	0.5	2	3075.66	3363
35	30	0.9	0.9	1	3050.37	3380
36	30	0.9	0.9	2	3088.41	3346
37	50	0.1	0.1	1	3009.46	3412
38	50	0.1	0.1	2	2989.26	3328
39	50	0.1	0.5	1	2959.76	3361
40	50	0.1	0.5	2	3061.69	3396
41	50	0.1	0.9	1	2995.85	3351
42	50	0.1	0.9	2	2997.68	3412
43	50	0.5	0.1	1	3069.07	3412
44	50	0.5	0.1	2	3055.19	3328

Table 7 (Cont.)

No. test	Pop	Pc	Pm	Replicate	Mean	Max
45	50	0.5	0.5	1	2950.31	3313
46	50	0.5	0.5	2	2918.5	3343
47	50	0.5	0.9	1	3051.51	3373
48	50	0.5	0.9	2	3006.68	3326
49	50	0.9	0.1	1	2997.34	3243
50	50	0.9	0.1	2	2972.7	3305
51	50	0.9	0.5	1	2979.29	3277
52	50	0.9	0.5	2	2949.64	3215
53	50	0.9	0.9	1	3056.63	3450
54	50	0.9	0.9	2	2999.5	3345

Calculations would be performed on a computer, using a MINITAB program to analyze data from design experiment. Shown in table 8.

Table 8 Analysis of Variance for the Output Voltage versus *Pop, Pc* and *Pm*

Source	df	Seq SS	Adj SS	Adj Ms	F	P
Pop	2	88361	88361	44181	27.32	0.0
Pc	2	4649	4649	2325	1.44	0.255
Pm	2	2956	2956	1478	0.91	0.413
Pop*Pc	4	8965	8965	2241	1.39	0.265
Pop*Pm	4	12300	12300	3075	1.90	0.139
Pc*Pm	4	5016	5016	1254	0.78	0.551
Pop*Pc*Pm	8	30063	30063	3758	2.32	0.048
Error	27	43669	43669	1617		
Total	53	195980				

Analysis of Variance

Hypothesis in the experiment are;

H_0: All Pop_i are equal, all Pc are equal and Pm are equal.

H_1: At least one pair are not equal.

The analysis of variance from MINITAB, show that the population size (*Pop*) and three-factor interactions (*Pop*Pc*Pm*) are significance at $\alpha = 0.05$.

There are 3 factors, Population Size (*Pop*), Probability Mutation (*Pm*), Probability Crossover (*Pc*), each at three levels, are of interest. Using double replicates of a 3^3 factorial design then there are 54 runs in this experiment. The experiment factors and treatment notation were shown in table 9.

There are three factors (*Pop, Pc,* and *Pm*) under study, and each factor is at three levels arranged in a factorial experiment. This is a 3^3 factorial design, and the 27 treatment combinations have 26 degrees of freedom. Each main effect has 2 degrees of freedom; each two-factor interaction has 4 degrees of freedom, three-factor interaction has 8 degree of freedom. There are 2 replicates; there are 53 total degrees of freedom and 27 total degrees of freedom.

Table 9 Factors Data

Factors	Level	Value
Population Size (*Pop*)	3	10, 30, 50
Probability Crossover (*Pc*)	3	0.1, 0.5, 0.9
Probability Mutation (*Pm*)	3	0.1, 0.5, 0.9

The some of squares may be calculated using the standard methods for factorial designs. In addition, if the factors are quantitative and equally spaced, the main effects may be partitioned into linear and quadratic components, each with a single degree of freedom. The two-factor interactions may be decomposed into linear x linear, linear x quadratic, quadratic x linear, and quadratic x quadratic effects.

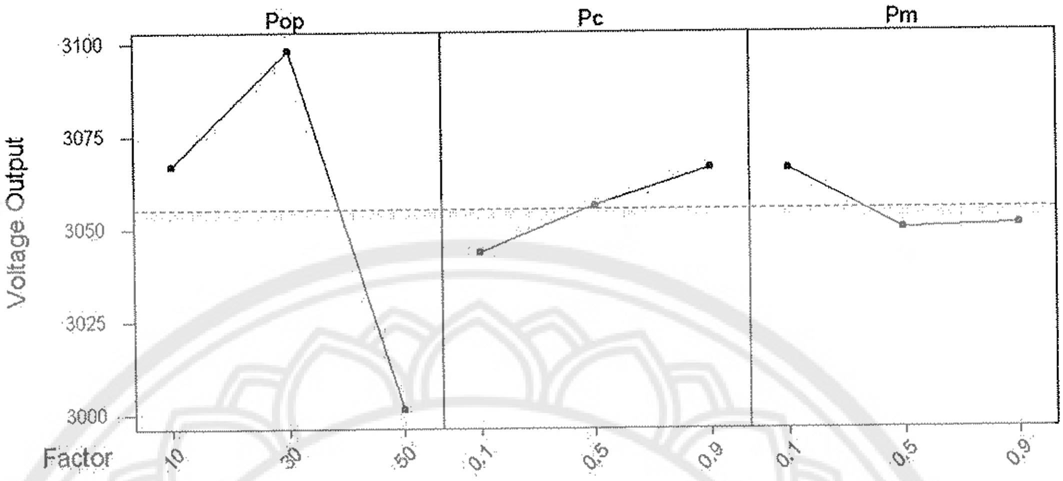

Figure 21 Main Effect Plots

Finally, the three-factor interaction ABC can be partitioned into eight single-degree-of-freedom component corresponding to linear x linear x linear, linear x linear x quadratic, so on. Such a breakdown for the three-factor interaction is generally not very useful.

From figure 21 the middle level (30) of population size (*Pop*) gives the best performance, the high level (0.9) of probability crossover (*Pc*) gives the best performance and the low level (0.1) of probability mutation (*Pm*) gives the best performance.

Table 10 Optimal Factors

Factors	Optimal factors
Population Size (Pop)	30
Probability Crossover (Pc)	0.9
Probability Mutation (Pm)	0.1

Plot of Residuals versus Order for Result

Plotting the residuals in time order of data collection is helpful in detecting correlation between the residuals. A tendency to have run of positive and negative residuals indicates positive correlation. This would imply that the independence assumption on the errors has been violated. This is a potentially serious problem and one that is difficult to correct, so it is important to prevent the problem if possible when the data are collected. Proper randomization of the experiment is and important step in obtaining independence.

Figure 22 displays the residuals at the time sequence of data collection for the output data. A plot of these residuals versus time is shown in figure 22, there is no reason to suspect any violation of the independence or constant variance assumptions.

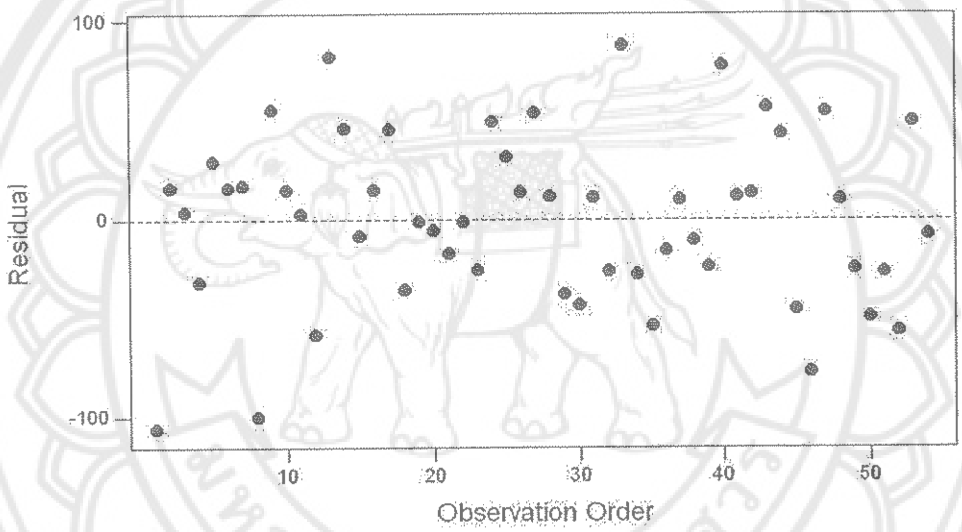

Figure 22 Residuals versus the Order of the Voltage Output

Plot of Residuals versus Fitted Values

If the model is correct and if the assumptions are satisfied, the residuals should be structure less; in particular, they should be unrelated to any other variable including the predicted response.

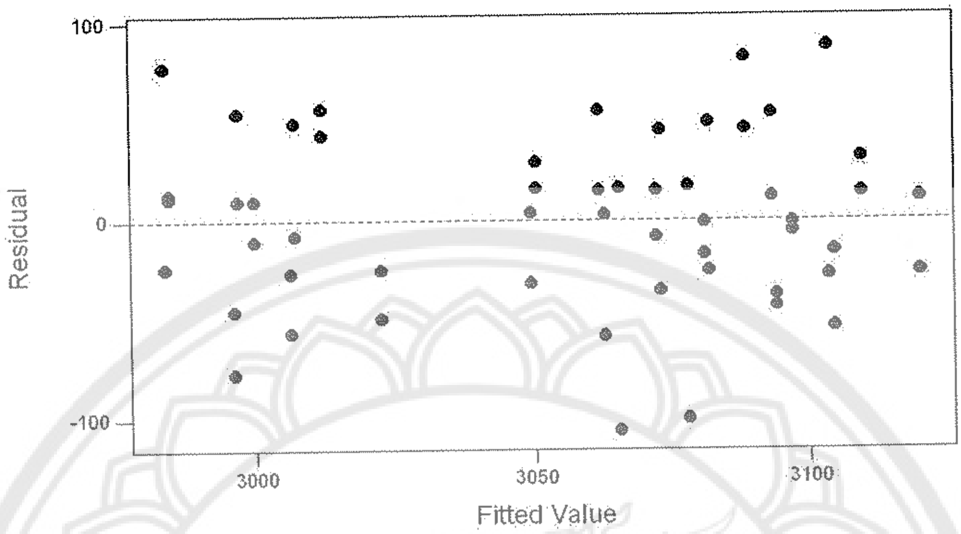

Figure 23 Residuals Versus the Fitted Values

From figure 23 this plot should not reveal any residuals versus the fitted value for the output data of figure 23 No unusual structure is apparent.

Normal Probability Plot of Residuals for Result

A check of the normality assumption could be made by plotting a histogram of the residuals. If the NID $(0, \sigma^2)$ assumption on the errors is satisfied, then this plot should look like a sample from a normal distribution centered at zero.

The normal probability plot is shown in figure 24 with the residuals plotted versus P_K x 100 on the right vertical scale. Note that the bottom of this figure also gives a dot diagram of the residuals. The general impression from examining this display is that the error distribution may be slightly skewed, with the right tail being longer than the left. The tendency of the normal probability plot to bend down slightly on the left side implies that the left tail of the error distribution is somewhat thinner than would be anticipated in a normal distribution; that is, the negative residuals are not quite as large as expected. This plot is not grossly non-normal, however.

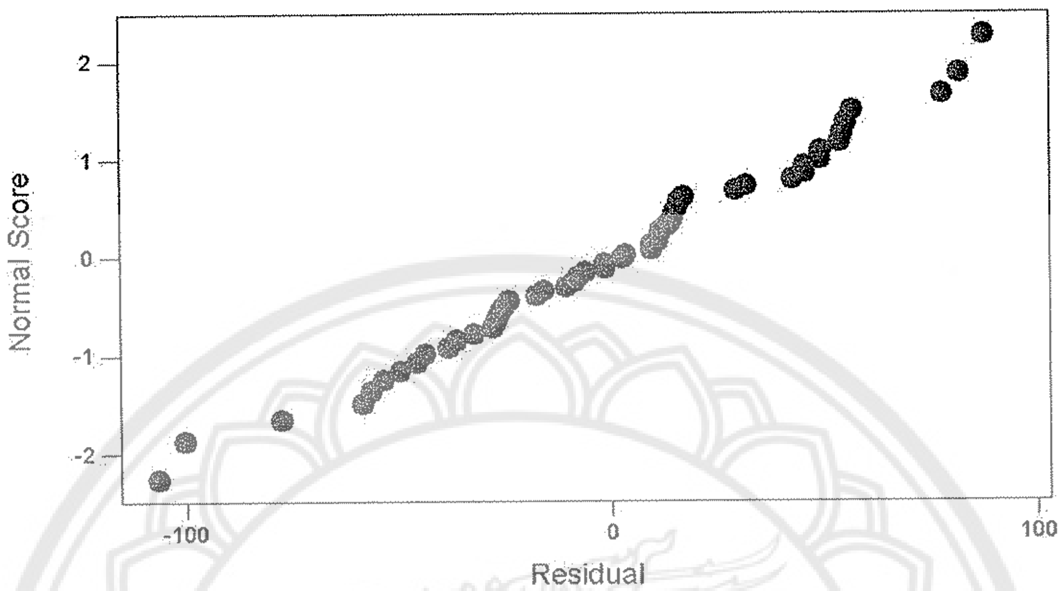

Figure 24 Normal Probability Plot of the Residuals

3. Experiment 3 Comparing the Output Voltage from STMM using GA with STMM Output.

This experiment compares the output voltage from STMM using GA with STMM output, using a statistical hypothesis. The appropriate test statistic to use for comparing two means of the output voltage in the experiment is Z-test.

Table 11 Statistic Data of the Output Voltage.

Groups	N	Mean	Std. dev	SE Mean
GA	763	3132.1	150	5.4
NonGA	720	2924.9	127	4.7

The Hypothesis to be test are

$H_0 : \mu_{GA} = \mu_{NonGA}$

$H_1 : \mu_{GA} > \mu_{NonGA}$

Note that is a one sided alternative hypothesis.

From table 11 Two random samples of n_{GA}= 763 and n_{NonGA} = 720 observations are taken the sample mean are $mean_{GA}$ = 3132.1 and $mean_{NonGA}$ = 2924.9, S^2_{NonGA} = 16141.8. The test statistic is

$$Z = \frac{\bar{X}_{GA} - \bar{X}_{NonGA}}{\sqrt{\frac{S^2_{GA}}{n_{GA}} + \frac{S^2_{NonGA}}{n_{NonGA}}}} \qquad (17)$$

where

Z	=	statistic test
$\bar{X}_{GA}$	=	mean of output voltage from STMM using GA
$\bar{X}_{NonGA}$	=	mean of output voltage from STMM
S^2_{GA}	=	variance of output voltage from STMM using GA
S^2_{NonGA}	=	variance of output voltage from STMM
n_{GA}	=	number of output voltage from STMM using GA
n_{NonGA}	=	number of output voltage from STMM

$$Z = \frac{3132.1 - 2924.9}{\sqrt{\frac{22420}{763} + \frac{16141.8}{720}}} = 28.79$$

From Statistic Table Z (Montgomery, 1997) Find that $Z_{0.05}$ = 1.645 so that the null hypothesis can be rejected.

Finally, we conclude that the mean of $Output_{GA}$ is greater than the mean of $Output_{NonGA}$ by $\alpha = 0.05$.

From table 11, the mean of output voltage from STMM is 2924.9 and the mean of output voltage from STMM using GA is 3132.1, show that the mean of output voltage from STMM using GA increase 207.23 approximate 7.084%.