ABSTRACT

MODELING OF ELECTRICITY CONSUMPTION OF DAVAO DEL SUR USING SEASONAL ARIMA

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This study aimed to analyze the characteristics of the monthly electricity consumption (in kWh) of Digos City and municipalities of Davao del Sur, generate a five-year forecast (2011 – 2015) and evaluate the implications and effects of the forecast data for Davao del Sur Electric Cooperative (DASURECO), local government and the economic activities of the province of Davao del Sur. There were two identified possible models that can be used for forecasting, namely, ARIMA(0,1,1) x $ARIMA(0,0,2)_{12}$ and ARIMA(0,1,1) x $ARIMA(0,1,1)_{12}$. Both models include seasonal terms. But only ARIMA(0,1,1) x $ARIMA(0,1,1)_{12}$ showed a better comparison between actual and forecast data. Hence, this was the final model used in generating five-year forecast of energy consumption of Davao del Sur, where the parameters MA(1) = 0.4639 and SMA(12) = 0.8479 are significant under the rule of t-statistics and p-value and also follows the invertibility condition of Box-Jenkins model evaluation. Result of five years of forecast from January 2011 to December 2015 showed a continuous upward trend of total energy (kWh) consumption with repeated pattern compared to previous months of previous years. There is an average rate of increase of 3.32% every year from 2011 to 2015 with a very high growth of 17.69% comparing 2015 from 2010. Also at the year 2015, a tremendous increase of 117.65% compared to the year 2000 will occur. It only means that the power consumption of Digos City and municipalities of Davao del Sur will double in 2015 or equivalently 181,684,132 kWh. Moreover, DASURECO is currently above 120% of the contracted energy. Therefore, DASURECO needs an estimated at least 2MW power generation plant as early as 2013 and another 3MW in 2015 that can supply power to them.

CHAPTER I
INTRODUCTION

In Mindanao region of the Philippines, the main source of electricity is the hydropower generated by the National Power Corporation (NPC) through the inflows of water from Lake Lanao's Agus River in Iligan City and Pulangi River in Bukidnon. For 20 years, hydropower comprises at least 90 percent of power source in the region. However, that percentage is depleting almost every year due to many reasons. One is the reducing capacity of the generators of NPC due to damages that need repairs and replacement but not acted upon. Second, the increasing demand of electricity which resulted to sourcing other form of power generation such as diesel-fed and coal-fed power plants because the NPC did not build new hydro plants. Lastly, another big factor is the climate change. The weather condition alters every year where most of the times it is abnormal like the global warming that is currently happening. El Niño that brings droughts is one of the effects of this phenomenon. This could hardly affect the economic and agriculture conditions of specific regions. In fact, from last quarter of 2009 up to second quarter of 2010, the whole Mindanao has experienced a power crisis due to El Niño which brought the Lake Lanao and Pulangi River into critical levels that forced the NPC to shut down some of its power generators and issued curtailment to power distribution utilities – the ones that deliver power to residences, commercial and industrial establishments, which then resulted to rotating brownouts in all areas in Mindanao region including Digos City and other municipalities of Davao del Sur (Sta.Cruz, Matanao, Bansalan, Magsaysay, Hagonoy, Padada, Kiblawan, Sulop, Malalag, Sta. Maria, Malita, Jose Abad Santos, Don Marcelino and Sarangani), which power is solely distributed by Davao del Sur Electric Cooperative (DASURECO).

At the height of the crisis in March 2010, out of 1,366 MW peak demand, dependable capacity was only logged at 751 MW which means lack of power of about 615 MW. These were the times of chaos. Davao del Sur and many other provinces, cities, and municipalities of Mindanao experienced 8 to 12 hours of power outages everyday for a period of 3 to 4 months. More business activities were highly hampered. Leaders of different chambers of commerce were continuously appealing to the national government to resolve the problem immediately. But still, many including ordinary people were blaming the government officials for not overseeing the situation and not making clear solution to the said crisis. As a result, the Department of Energy (DOE) was tasked by the high ranking national officials to find immediate solution to the power crisis in Mindanao. These were the moments that the NPC were outsourcing alternative energy such as generated by diesel/gasoline-fed and coal-fed power plants, which are more expensive than the power generated by hydro plants. This is the major reason of higher electricity rates for several months, which irritated a lot of consumers; a power rate-hike that shocked the public because for many years Mindanao electricity rate is much cheaper than Luzon and Visayas regions.

Now, any individual living in Mindanao especially in Davao del Sur can ask himself these questions, "Due to rapid demand of energy and climate change, does power shortage will be continuously being felt by consumers now and for the coming years? What is the possibility that the cost of electricity will raise to an amount beyond the capability of most people especially the poorest of the poor despite the fact that the main source is a renewable energy? Is there any early plan or action by the local and national government to prevent another power crisis in the near future that could possibly damage the integrity and economy of Davao del Sur, Mindanao and even the whole country?"

Thus, by looking ahead the situation of the power consumption of Davao del Sur region would help a lot. One tool is through mathematical predictions of Davao del Sur's energy requirement for five years from now using the historical data. In the fields of mathematics and operations research, predictions could mean forecasting. The term forecasting is often thought to apply solely to problems in which we predict the future. It is a necessary input to planning, whether in business, or in government.

Significance of the Study

The significance of this study is that one can analyze the future status of the electricity consumption (in kilowatt-hour or kWh) of Digos City and nearby municipalities of Davao del Sur for the next five years. Through this, the local and even national government can picture out and evaluate the changes of electricity consumption year by year and even month by month. Furthermore, the energy forecast will also give hints for the right action in preparing programs, projects and initiatives on energy conservation so that one of the very severe experiences of power crisis on the 1st semester of 2010 will never repeat again in which more businesses as well as the whole economic condition of Davao del Sur were very much affected. It would, likewise, gain attraction to local and foreign investors to invest more on energy generation especially if rapid growth of electricity requirement will be seen. In effect, it would boost the economy of city and municipalities of Davao del Sur because it will stop the worries of different businesses that rely much on electricity. Consequently, enough supply of electricity means stable and growing businesses which will then create more jobs aside from the lower probability of having another power crisis.

Objectives of the Study

The main objectives of the study were: (1) to analyze the characteristics of the monthly electricity consumption (in kWh) of Davao del Sur; (2) to generate a five-year forecast (2011 – 2015) of monthly electricity consumption; and (3) to identify and evaluate the implications or effects of the obtained forecast electricity consumption for the distribution utility, local government and the economic activities of Digos City and municipalities of Davao del Sur.

Scope and Limitation

This study focused only on the total monthly historical data of Davao del Sur electricity consumption (in kilowatt-hour or kWh) from January 2000 to December 2010 to be primarily used in forecasting, taken from Davao del Sur Electric Cooperative (DASURECO) – the sole distribution utility that delivers power to Digos City and nearby municipalities of Davao del Sur. It does not include historical data by group of consumers such as residential, commercial and industrial. Moreover, the true process of collection of data is beyond the concern of the researcher.

CHAPTER II
MATERIALS AND METHODS

Analysis of Data

The data gathered, i.e. Monthly Energy (kWh) Consumption of Digos City and municipalities of Davao del Sur from January 2000 to December 2010, were plotted in MINITAB for initial analysis of its characteristics. The autocorrelation function (ACF) was graphed also in order to determine further if the series is stationary (mean and variance are constant over time) and non-seasonal.

Model Identification and Estimation

The autocorrelation function (ACF) and a partial autocorrelation function (PACF) of the stationarized and deseasonalized were plotted to identify the possible and appropriate models based on Box-Jenkins assumptions. Using MINITAB, the coefficients of the parameters and residuals were analyzed to come up possible model(s) that will fit the original data. Consequently, the identified models were examined if all the parameters are significant using the assumptions of the t-statistics and p-value.

Model Validation and Forecasting

The possible ARIMA models were validated to measure its reliability and accuracy of its forecast. The ACF of the residual series of identified models were plotted to know if they are uncorrelated or independent and normally distributed. If most, if not all, lags are significantly not different from zero, thus the model is good and the forecast could estimate and simulate the true values in the future. Consequently, the models were run again through MINITAB to forecast energy (kWh) consumption of Digos City and municipalities of Davao del Sur from January 2009 to December 2010 to compare them to the actual values of the same period (others term it as “interpolation”). This validation process was the major factor in determining the final model to be used in forecasting. The final model was used again in getting the five-year monthly forecast values.

CHAPTER III

RESULTS AND DISCUSSION

Model Identification

The graph below (Figure 1) shows the Monthly Energy (kWh) Consumption of Digos City and municipalities of Davao del Sur from January 2000 to December 2010. Based on the figure, energy consumption has an increasing trend from January 2000 to December 2010. Over all, it fluctuates from positive to negative monthly growth and vice-versa. Clearly, the time series graph exhibits no constant mean and variance over time. Thus, it can be said that the data is non-stationary and a transformation should be done in order to attain stationarity condition which is the very first assumption before using the Autoregressive Integrated Moving Average (ARIMA) models.

Figure 1. A run sequence plot of Monthly Total Energy (kWh) Consumption of Digos City and municipalities of Davao del Sur from January 2000 to December 2010.

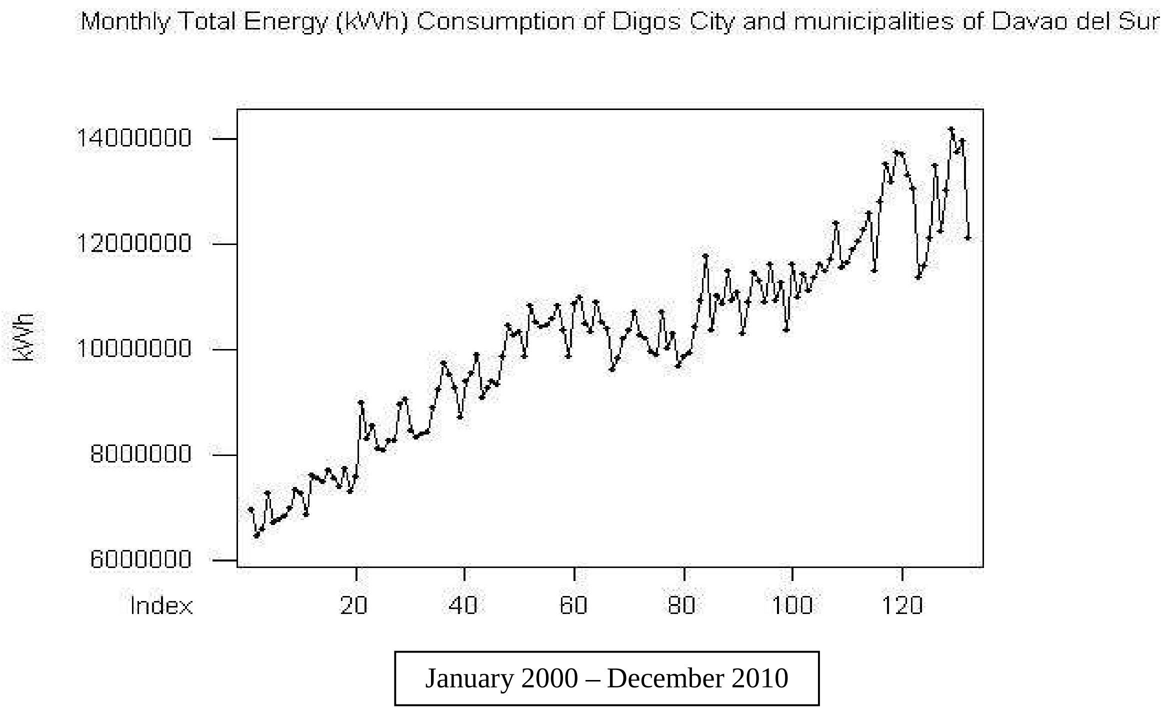


Figure 2. A run sequence plot of Monthly Energy (kWh) Consumption of Digos City and municipalities of Davao del Sur from January 2000 to December 2010 after first differencing.

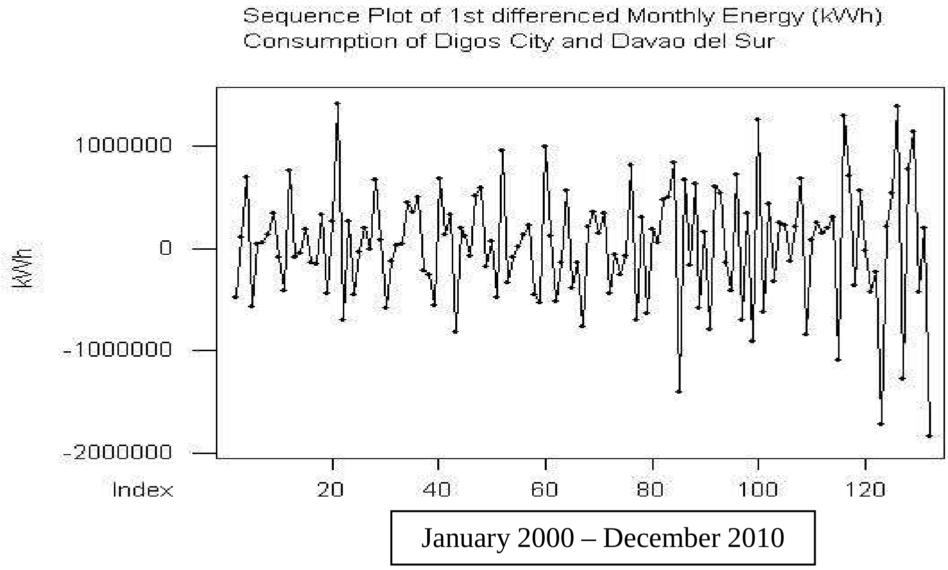
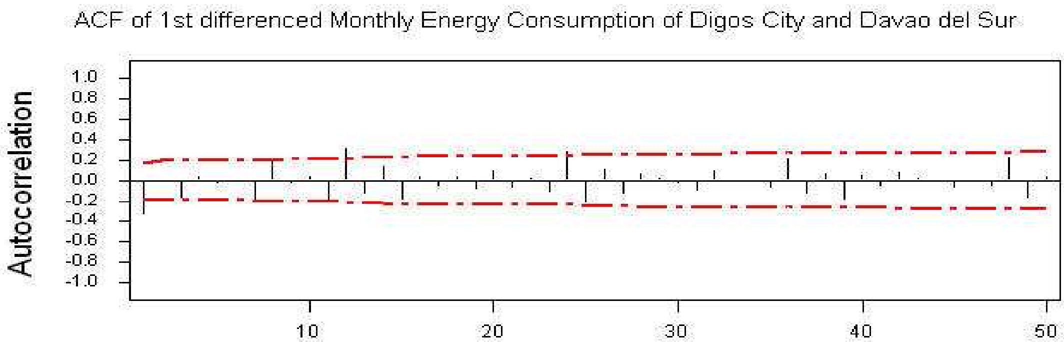
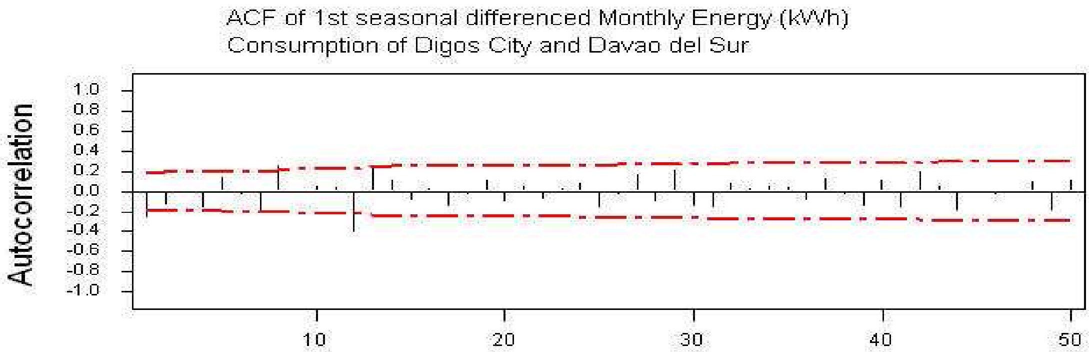


Figure 3. An autocorrelation function (ACF) plot of Monthly Energy (kWh) Consumption of Digos City and municipalities of Davao del Sur from January 2000 to December 2010 after first differencing.



Lag	Corr	T	LBQ
1	-0.33	-3.75	14.37
2	0.01	0.12	14.39
3	-0.16	-1.69	17.99
4	0.03	0.33	18.13
5	-0.02	-0.21	18.19
6	0.01	0.13	18.21
7	-0.20	-2.02	23.79
8	0.20	2.01	29.71
9	-0.02	-0.21	29.78
10	0.03	0.32	29.93
11	-0.19	-1.81	35.17
12	0.32	2.94	49.72
13	-0.13	-1.12	52.13
14	0.14	1.23	55.13
15	-0.18	-1.59	60.26
16	0.03	0.29	60.44
17	-0.05	-0.41	60.81
18	0.04	0.34	61.07
19	-0.08	-0.67	62.04
20	0.09	0.78	63.40
21	-0.06	-0.53	64.03
22	0.02	0.13	64.07
23	-0.11	-0.88	65.88
24	0.28	2.32	78.68
25	-0.21	-1.68	86.03
26	0.11	0.85	88.02
27	-0.12	-0.96	90.62
28	0.07	0.54	91.46
29	0.02	0.14	91.52
30	-0.02	-0.19	91.62
31	-0.10	-0.73	93.23
32	0.09	0.67	94.59
33	-0.00	-0.04	94.60
34	0.01	0.09	94.63
35	-0.06	-0.46	95.30
36	0.20	1.55	102.96
37	-0.12	-0.91	105.70
38	0.06	0.48	106.49
39	-0.17	-1.28	112.19
40	0.05	0.37	112.68
41	-0.05	-0.39	113.23
42	0.08	0.61	114.63
43	0.02	0.16	114.72
44	-0.00	-0.03	114.72
45	-0.06	-0.43	115.45
46	0.01	0.09	115.48
47	-0.05	-0.35	115.97
48	0.22	1.57	125.85
49	-0.17	-1.20	131.87
50	0.03	0.23	132.10

Figure 4. An autocorrelation function (ACF) plot of Monthly Energy (kWh) Consumption of Digos City and municipalities of Davao del Sur from January 2000 to December 2010 after first seasonal differencing.



Lag	Corr	T	LBQ	Lag	Corr	T	LBQ	Lag	Corr	T	LBQ	Lag	Corr	T	LBQ	Lag	Corr	T	LBQ
1	-0.25	-2.74	7.67	13	0.25	2.05	57.58	25	-0.16	-1.20	70.91	37	0.12	0.87	95.16	49	-0.18	-1.18	127.32
2	-0.12	-1.24	9.45	14	0.10	0.81	59.00	26	-0.02	-0.18	71.00	38	-0.03	-0.20	95.31	50	0.11	0.73	129.81
3	0.00	0.01	9.45	15	-0.07	-0.57	59.72	27	0.16	1.23	75.09	39	-0.14	-0.97	98.64				
4	-0.15	-1.52	12.27	16	0.02	0.19	59.80	28	-0.09	-0.67	76.34	40	0.10	0.72	100.55				
5	0.14	1.37	14.67	17	-0.14	-1.07	62.42	29	0.20	1.52	83.01	41	-0.15	-1.08	104.95				
6	-0.02	-0.17	14.71	18	-0.02	-0.13	62.46	30	-0.13	-0.97	85.86	42	0.20	1.38	112.38				
7	-0.18	-1.78	18.97	19	0.10	0.79	63.93	31	-0.15	-1.07	89.38	43	0.05	0.35	112.88				
8	0.26	2.46	27.56	20	-0.09	-0.70	65.09	32	0.08	0.58	90.47	44	-0.17	-1.19	118.74				
9	-0.01	-0.07	27.56	21	0.05	0.40	65.48	33	0.03	0.20	90.60	45	-0.01	-0.06	118.76				
10	0.05	0.41	27.84	22	-0.07	-0.53	66.19	34	0.06	0.41	91.16	46	-0.03	-0.17	118.88				
11	0.04	0.35	28.04	23	0.03	0.21	66.31	35	0.04	0.26	91.38	47	0.01	0.09	118.92				
12	-0.40	-3.59	49.11	24	0.08	0.58	67.16	36	-0.08	-0.59	92.55	48	0.10	0.68	120.95				

Since the new series exhibits seasonality, then seasonal terms will be included in the selection and formulation of the model. The identification of the possible ARIMA(p,d,q) x ARIMA(P,D,Q) models, where p is the order of autoregressive, d is the number of nonseasonal differencing, q is the order of moving average, P is the order of seasonal autoregressive, D is the number of seasonal differencing, and Q is the order of seasonal moving average will be based on Box-Jenkins model identification and assumptions on the pattern of the autocorrelation. From Figure 3, where the ACF cut-off at lag 1, it suggests that the possible nonseasonal ARIMA(p,d,q) model is ARIMA(0,*1,1*). When one seasonal differencing was applied, Figure 4 cut-off at lag 12 that suggests a possible seasonal ARIMA$(0,1,1)_{12}$ model.

Model Estimation

Table 1 displays the estimated coefficients of the parameters of the two identified models, ARIMA(0,1,1) x ARIMA$(0,0,2)_{12}$ and ARIMA(0,1,1) x ARIMA$(0,1,1)_{12}$ with the corresponding standard deviation, t-statistics and p-value of each parameter of each model. Both ARIMA models have significant parameters. From the table of final estimates, the coefficients of MA(1), SMA(12) and SMA(24) of ARIMA(0,1,1) x ARIMA$(0,0,2)_{12}$ are significant because its t-statistics values are 6.38, -3.16 and -2.53, respectively and their p-values are 0.000, 0.002 and 0.013. Also, the coefficients of MA(1), SMA(12)) of ARIMA(0,1,1) x ARIMA$(0,1,1)_{12}$ are significant because its t-statistics values are 5.22, and 8.27, respectively and their p-values are all zeros. Both models follow invertibility conditions because /MA(1)/ < 1, /SMA(12)/ < 1 and /SMA(24)/ < 1. Therefore, both ARIMA models are good candidates to fit the original data and can be used in forecasting future values.

Table 1. The final estimates of the parameters of ARIMA(0,1,1) x ARIMA$(0,0,2)_{12}$ and ARIMA(0,1,1) x ARIMA$(0,1,1)_{12}$.

Final Estimates of the Parameters				
ARIMA (0, 1, 1) x ARIMA $(0, 0, 2)_{12}$				
Type	**Coef**	**StDev**	**T-stat**	**P-value**
MA(1)	0.5097	0.0799	6.3800	0.0000
SMA(12)	-0.3253	0.1029	-3.1600	0.0020
SMA(24)	-0.2785	0.1103	-2.5300	0.0130
ARIMA (0, 1, 1) x ARIMA $(0, 1, 1)_{12}$				
MA(1)	0.4639	0.0889	5.2200	0.0000
SMA(12)	0.8479	0.1025	8.2700	0.0000

Model Validation

One of the processes of model diagnostics is to examine the autocorrelation plot of the residuals of the fitted model against the original series. From the residual analysis, residuals are uncorrelated and independent using both ARIMA models. Second, which is the most common and effective measure of reliability of the model is comparing the generated forecast based on the partial data with known original observations. The partial data, January 2000 to December 2008, was used to generate forecast values from January 2009 to December 2010 using the two identified models ARIMA(0,1,1) x ARIMA$(0,0,2)_{12}$ and ARIMA(0,1,1) x ARIMA$(0,1,1)_{12}$ and compared these to the actual data which are shown in Figure 5 and Figure 6, respectively.

Based from the two figures below, it is very clear that the most appropriate and valid model is ARIMA(0,1,1) x ARIMA(0,1,1)$_{12}$, which is ready to be used in forecasting 2011 to 2015 energy (kWh) consumption of Davao del Sur.

Figure 5. Time Series Plot of actual values from January 2000 to December 2010 vs forecast values from January 2009 to December 2010 using ARIMA(0,1,1) x ARIMA(0,0,2)$_{12}$.

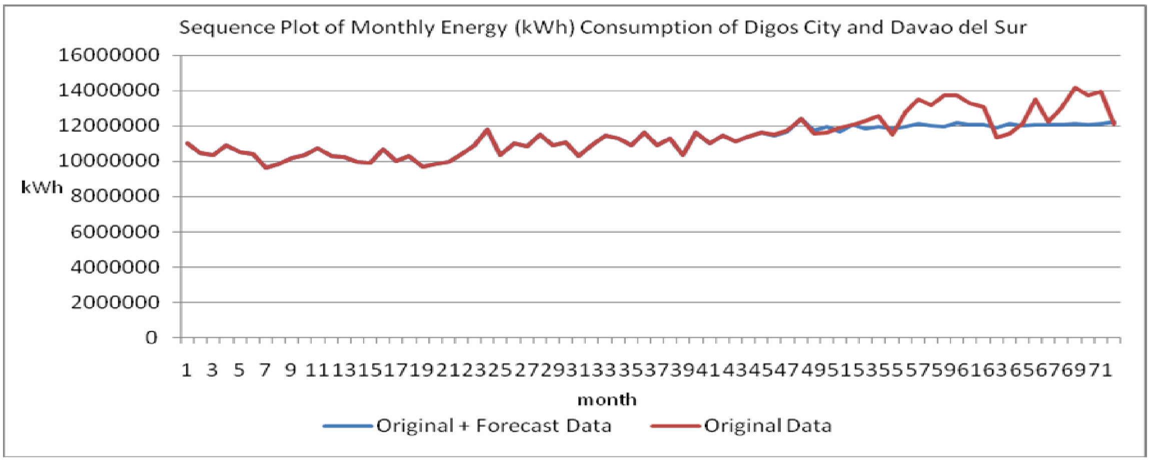
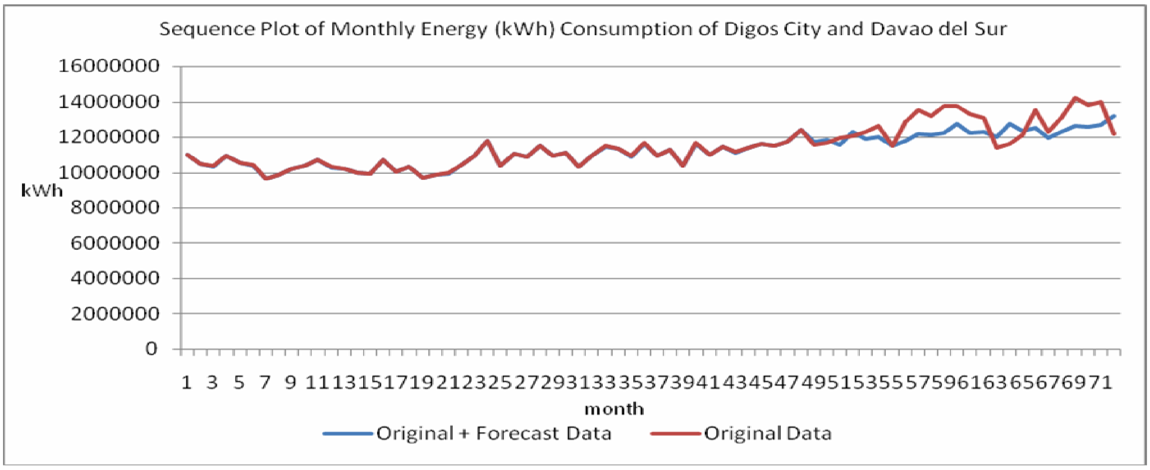


Figure 6. Time Series Plot of actual values from January 2000 to December 2010 vs forecast values from January 2009 to December 2010 using ARIMA(0,1,1) x ARIMA(0,1,1)$_{12}$.



The graph above, Figure 6, shows only -3.29% difference or Mean Percentage Error (MPE) on month-to-month and -3.65% MPE on cumulative 24-month comparisons (forecast vs actual data). It only means that the forecast is slightly smaller than the actual data. On the other hand, Figure 5 has -4.97% and -5.38% MPEs on month-month and cumulative 24-month comparisons, respectively. According to many statisticians and economists, an MPE of 5% or less in forecast versus actual values is a very good indication of a reliable forecast or budget in the field of business and industry. Thus, predicting energy (kWh) consumption of Digos City and Davao del Sur using ARIMA(0,1,1) x ARIMA$(0,1,1)_{12}$ with only a MPE of -3.29% compared to actual values is a denotation of a very good forecasting model.

Forecasting

From the software (MINITAB) used, the final model was used in determining the forecast of Monthly Energy (kWh) Consumption of Davao del Sur from January 2011 to December 2015. The result of the forecast (in red) including the original values (in black) can be found on Table 2 and being illustrated in the time series plot of Figure 7.

Table 2 shows an average rate of increase of 3.32% every year from 2011 to 2015 with a very high growth of 17.69% comparing 2015 from 2010, just a span of five years. That is about 27,314,020 kWh increase in a year or 2,276,168 kWh/month. If a residential consumer consumes 100 kWh/month, then an estimated 22, 272 homes will need electricity. The current monthly contract of DASURECO from NPC is 10,469,424 kWh per month or 125,633,088 kWh in a year. DASURECO or any electric distribution utility is only allowed to buy power from NPC up to 120% of the contracted energy. Beyond that, the company will be penalized by a certain amount depending on the contract. Clearly, the actual consumption of Davao del Sur in the year 2010 is already above the 120% cap of 150,759,706 kWh.

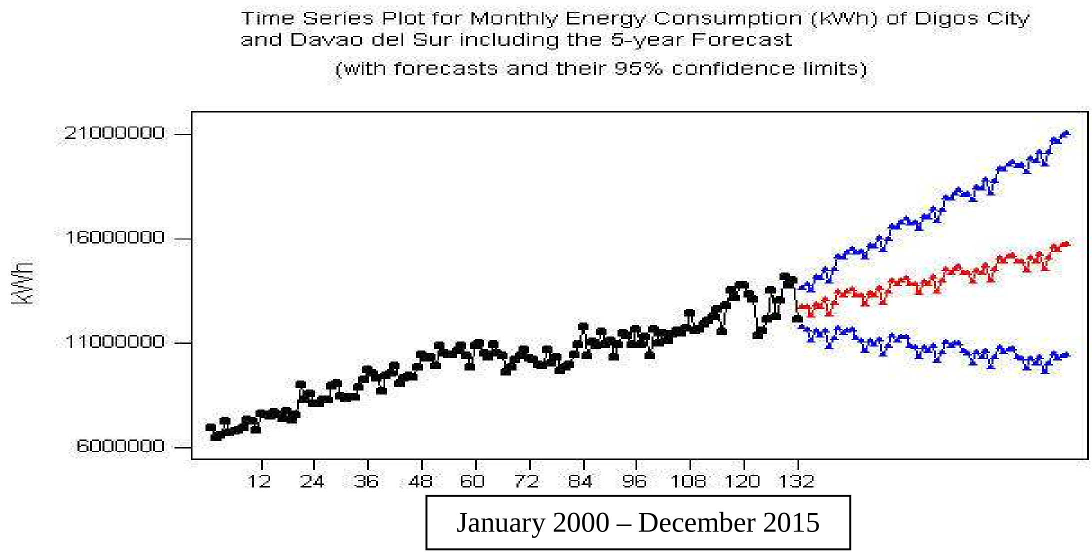
Moreover, a tremendous increase of 117.65% in the year 2015 versus 2000 will occur. It only means that the power consumption of Digos City and municipalities of Davao del Sur will double in 2015 or equivalently 181,684,132 kWh. Therefore, DASURECO needs an estimated at least 2MW power generation plant as early as 2013 and another 3MW in 2015 that can supply power to them. DASURECO must not rely on NPC alone because the National Power Corporation is zero reserve at the moment. Thus, without another source of electricity in two to three years from now means another shortage of electricity in the province of Davao del Sur, similar to what had happened on the first half of 2010.

Table 2. The 11-year original data and 5-year forecast values of the Monthly Energy (kWh) Consumption of Digos City and municipalities of Davao del Sur.

Monthly Energy (kWh) Consumption of Digos City and Municipalities of Davao del Sur

	January	February	March	April	May	June	July	August	September	October	November	December	Total	% Growth
2000	6,931,714	6,451,579	6,564,737	7,268,332	6,706,527	6,754,536	6,818,859	6,966,178	7,320,116	7,243,677	6,838,593	7,610,789	**83,475,637**	
2001	7,526,616	7,489,337	7,684,563	7,546,192	7,393,008	7,729,522	7,286,690	7,562,373	8,984,416	8,278,801	8,549,826	8,100,461	**94,131,805**	**12.77%**
2002	8,069,654	8,277,634	8,268,634	8,954,039	9,039,734	8,462,930	8,341,106	8,378,107	8,423,428	8,882,246	9,240,459	9,742,659	**104,080,630**	**10.57%**
2003	9,531,411	9,272,189	8,713,061	9,408,922	9,549,410	9,892,908	9,069,640	9,280,167	9,401,894	9,331,301	9,852,993	10,447,881	**113,751,777**	**9.29%**
2004	10,270,414	10,349,964	9,875,143	10,846,181	10,518,805	10,440,093	10,458,218	10,602,857	10,838,612	10,383,777	9,852,993	10,861,539	**125,298,596**	**10.15%**
2005	10,994,825	10,479,578	10,339,244	10,917,081	10,529,103	10,391,372	9,627,992	9,848,713	10,208,501	10,360,601	10,717,237	10,276,385	**124,690,632**	**-0.49%**
2006	10,219,146	9,962,891	9,887,917	10,712,318	10,007,205	10,318,570	9,678,975	9,870,631	9,938,811	10,423,550	10,931,802	11,780,687	**123,732,503**	**-0.77%**
2007	10,367,058	11,040,266	10,876,231	11,512,122	10,931,324	11,096,561	10,304,142	10,916,648	11,464,319	11,324,495	10,910,181	11,638,460	**132,381,807**	**6.99%**
2008	10,933,416	11,280,951	10,364,661	11,631,468	11,007,848	11,448,909	11,130,089	11,386,387	11,618,009	11,492,900	11,716,100	12,414,884	**136,425,622**	**3.05%**
2009	11,569,079	11,655,779	11,920,982	12,073,176	12,277,067	12,593,547	11,506,124	12,818,325	13,539,911	13,185,573	13,761,337	13,742,993	**150,643,893**	**10.42%**
2010	13,316,051	13,083,454	11,362,986	11,582,174	12,126,342	13,526,392	12,253,029	13,039,461	14,190,761	13,769,425	13,982,525	12,137,512	**154,370,112**	**2.47%**
2011	12,717,220	12,715,092	12,305,526	12,873,656	12,719,868	13,073,401	12,388,608	12,899,766	13,434,952	13,285,482	13,480,082	13,571,119	**155,464,772**	**0.71%**
2012	13,263,457	13,261,329	12,851,762	13,419,893	13,266,105	13,619,638	12,934,845	13,446,003	13,981,189	13,831,719	14,026,318	14,117,356	**162,019,614**	**4.22%**
2013	13,809,693	13,807,566	13,397,999	13,966,129	13,812,341	14,165,875	13,481,081	13,992,239	14,527,425	14,377,956	14,572,555	14,663,593	**168,574,452**	**4.05%**
2014	14,355,930	14,353,802	13,944,236	14,512,366	14,358,578	14,712,111	14,027,318	14,538,476	15,073,662	14,924,192	15,118,791	15,209,829	**175,129,291**	**3.89%**
2015	14,902,166	14,900,039	14,490,472	15,058,603	14,904,814	15,258,348	14,573,555	15,084,713	15,619,899	15,470,429	15,665,028	15,756,066	**181,684,132**	**3.74%**

Figure 7. The time series plot of the Actual Monthly Energy Consumption (kWh) of Digos City and Municipalities of Davao del Sur from January 2000 to December 2010 including the forecast values from January 2011 to December 2015.



- The End -