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DEMAND SIDE MANAGEMENT FOR ELECTRIC DISTRIBUTION UTILITY

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ABSTRACT

This research paper aims to provide an in-depth analysis of demand side management (DSM) strategies for electric distribution utilities. With the increasing global demand for electricity, utilities are facing challenges related to grid reliability, energy efficiency, and environmental sustainability. DSM programs offer a promising solution by actively involving consumers in optimizing energy consumption patterns. This research explores various DSM approaches, their benefits, challenges, and the role of emerging technologies in enhancing the effectiveness of these strategies.

KEYWORDS: demand, demand side management, distribution utilities, electricity, consumption.

INTRODUCTION

This section presents the Demand Side Management programs and objectives objectives that been applied for the system of each electric distribution utility. Demand Side Management programs may reduce demands over all or most periods of the day, month, or year but may save even greater demand during peak periods.

It has been traditionally seen as a means of reducing peak electricity demand so that utilities can delay building further capacity. In fact, by reducing the overall load on an electricity network, DSM has various beneficial effects, including mitigating electrical system emergencies, reducing the number of blackouts, and increasing system reliability. Possible benefits can also include reducing dependency on expensive imports of fuel, reducing energy prices, and reducing harmful emissions to the environment. Finally, DSM has a major role to play in deferring high investments in generation, transmission, and distribution networks. Thus, DSM applied to electricity systems provides significant economic, reliability and environmental benefits. When DSM is applied to the consumption of energy in general—not just electricity but fuels of all types—it can also bring significant cost benefits to energy users (and corresponding reductions in emissions). Opportunities for reducing energy demand are numerous in all sectors and many are low-cost, or even no cost, items that most enterprises or individuals could adopt in the short term, if good energy management is practiced. It produces a more reliable and economical operation, while maintaining the power system's operational integrity. Evaluate efficiency and determine where energy- reducing strategies such as moving on-peak usage into off-peak periods or shifting from one rate schedule to another could help to improve the bottom line.

OBJECTIVES

Demand Side Management options generally primarily address one of the following objectives. Peak Clipping which seeks to reduce the utility load primarily during periods of peak demand, valley filling aims to improve the system load factor by building load in off-peak periods which increases the total energy consumption without increasing peak demand. Load shifting objective means a shift from peak to off-peak periods, thus reducing peak demand but not reducing total energy consumption. Energy efficiency or Conservation objective seeks to reduce end use consumption to help customers control their monthly electric bills resulting in net reduction in both total energy consumption and peak demand. The fifth objective, strategic load growth, seeks to increase the energy consumption in specific geographic areas or economic sectors. The last objective is the Flexible Load Shape. This objective seeks to vary the reliability or quality of service for specific customer class or areas, thus influencing load shapes temporarily on a need to basis rather than permanently.

3. DESIGN AND METHODS

This section presents the design and methods used in the study.

Energy demand management, also known as demand-side management (DSM) or demand-side response (DSR), is the modification of consumer demand for energy through various methods such as financial incentives and behavioral change through education.

Usually, the goal of demand-side management is to encourage the consumer to use less energy during peak hours, or to move the time of energy use to off- peak times such as nighttime and weekends.

Peak demand management does not necessarily decrease total energy consumption, but could be expected to reduce the need for investments in networks and/or power plants for meeting peak demands. An example is the use of energy storage units to store energy during off-peak hours and discharge them during peak hours. A newer application for DSM is to aid grid operators in balancing intermittent generation from wind and solar units, particularly when the timing and magnitude of energy demand does not coincide with the renewable generation.

Since demand can often vary hourly, daily, or monthly, specific utility surcharges can be reduced or eliminated by pinpointing the source and length of the peak demand usage. Demand-Side Management can be configured to shed non-critical loads during situations where peak electrical demand threatens to increase your electrical bill and reduce the operating profit of your facility.

Traditionally, during power system planning, emphasis was placed on building a strong bulk power generation and transmission system, while minor attention was given to the demand side. (Moran, et., al, 1959) The load-leveling problem has been recognized from the early days of the power system, and various measures have been devised with the objective to encourage electricity use at off-peak periods. (Holmes, et., al, 1929) However, load has been something to follow, and if necessary to shed and restore. (Moran, et., al, 1959) The design and operation of electricity markets deviates from the standard economic theory, mainly since the demand side is largely disconnected from the market. (Stoft, et., al, 2002) It was not until the 1970s when critics argued that, at some large extent, it would be more cost effective to reduce the demand for electricity rather than to increase supply by expanding the generation capacity. Following the oil embargo in 1973 and the subsequent cost increase in the electricity delivery service, DSM programs started slowly to appear within the strategic plans of electric utilities. By that time, industry organizations realized the importance of load management. (Gellings, et., al, 1981).

The concept of Demand Side Management (DSM) was originated in the 1970's in response to the impacts of energy shocks to the electricity utility industry. Due to higher energy prices consumers are forced to spend more money on energy and less on other goods, as a result business activity slowed down. To reduce the electricity demand, the utilities began providing incentives to customers who curtailed their electricity use and thus the Demand Side Management came into existence.

Electricity demand is rapidly increasing with the increase in new infrastructures, new businesses and homes, and a huge rise in the use of air conditioners. This put increasing pressure on the energy supplying utilities and forced them for large investments to cope with short peaks in demand. Demand management mainly aims to encourage a change in the use of electricity.

Residential load is the largest contributor for the increase in the peak demand. The importance of the residential consumers in the national demand of electrical energy and power has increased rapidly. The increase in the number of residential consumers of electrical power has been greater than the growth of the population. The residential load is responsive to the weather factors in the country, the lifestyle of the people and the types and number of the appliances that they are using. The Demand Side Management related to residential consumers allows the consumers to control their loads and to know the behavior of their main electric appliances in relation to the demand of electrical energy. By various DSM techniques, the consumers can know their energy consumption profile and manage their loads accordingly.

During the peak period, most generator units generate close to the capacity limit, the electric system becomes stressed, and the reliability of the whole system is damaged.

Thus, the system becomes more vulnerable to failure and the probability for the loss of load increases. The peak demand can be reduced by direct control of residential loads, but they were not much considered because of lack of proper control equipment. It is important to formulate energy conservation policies and to develop various DSM techniques, aiming specifically for residential consumers, seeking for load curve modulation and rational use of energy.

The responsibility of every utility to develop and implement DSM plans is provided for under Section 3 of the Framework for DSM in the Philippines issued by the Energy Regulatory Board (ERB). It is aimed at the electric utilities' activities designed to encourage and influence their customers' use of electricity in ways that will produce desired changes to both the timing and level of electricity demand or load shapes.

Demand Side Management options generally primarily address one of the following objectives. Peak Clipping which seeks to reduce the utility load primarily during periods of peak demand, valley filling aims to improve the system load factor by building load in off-peak periods which increases the total energy consumption without increasing peak demand. Load shifting objective means a shift from peak to off-peak periods, thus reducing peak demand but not reducing total energy consumption. Energy efficiency or Conservation objective seeks to reduce end use consumption to help customers control their monthly electric bills resulting in net reduction in both total energy consumption and peak demand. The fifth objective, strategic load growth, seeks to increase the energy consumption in specific geographic areas or economic sectors. The last objective is the Flexible Load Shape. This objective seeks to vary the reliability or quality of service for specific customer class or areas, thus influencing load shapes temporarily on a need to basis rather than permanently.

4. RESULTS AND DISCUSSION

Presentation of Energy Demand of Various Electric Utilities using Load Curve

Months	2013	2014	2015	2016	2017	2018
January	74,195.22	80,317.45	81,729.45	92,638.28	94,106.78	102,859.03
February	76,742.73	78,847.91	83,987.63	94,770.02	101,502.75	109,859.88
March	79,746.46	79,599.64	83,666.34	96,683.47	104,912.79	112,568.46
April	91,750.55	91,646.26	94,095.30	108,274.72	108,460.84	118,617.53

The following figures present the average demand, peak demand, and rated capacity of various electric distribution utilities in Batangas Province. The load curves were plotted in MATLAB based on the data provided by the distribution utilities.

Average Demand. The average load is the amount of power that needs to be delivered to the customers. The distribution system delivers a variety of loads depending upon the consumer's demand. These demands vary constantly which leads to the variable loading of the system. This variation in the system depends on time and can be considered for daily, monthly, or yearly. It can also be represented graphically using load curve.

Table 4.1.1: Average Demand (kWh) of BATELEC II.

Months	2013	2014	2015	2016	2017	2018
May	92,218.57	100,365.07	102,178.55	113,305.61	125,767.71	129,302.00
June	82,601.40	99,592.70	106,723.49	113,058.41	123,328.54	122,050.25
July	84,881.45	80,335.13	99,258.65	106,600.95	117,611.02	118,177.55
August	84,881.45	91,213.70	98,595.83	107,219.56	117,856.16	120,079.60
September	80,997.47	100,014.91	100,014.91	110,769.50	118,544.89	119,554.41
October	86,190.39	98,476.49	98,729.42	105,265.67	117,526.58	123,604.82
November	83,158.12	100,116.03	100,116.03	103,818.98	112,210.02	119,494.12
December	87,000.50	94,527.16	94,527.16	103,370.63	106,565.96	118,762.44
Average	83,697.03	91,254.37	95,301.90	104,647.98	112,366.17	117,910.84

Table 4.1.1 shows the average demand of BATELEC II from year 2013 to 2018. The data presented in the table is the average demand from the customers of BATELEC II which were classified as residential, commercial, industrial and others.

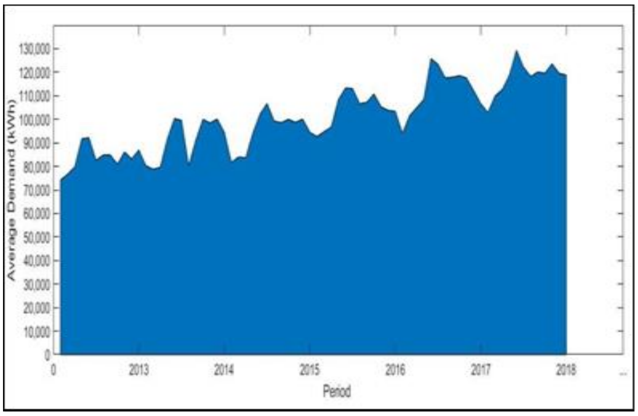

Figure 4.1.1 Average Demand (kWh) of BATELEC II (2013-2018)

The data from Table 4.1.1 were plotted in the graph. From the graph, it can be observed that the average demand of BATELEC II on year 2013 to 2018 ranges around 74,000 kW up to 130,000 kW per hour. It can also be noted that the variation of average demand was constant and steadily increased from 2013 to 2018.

Table 4.1.2: Average Demand (kWh) of FBPC.

Months	2013	2014	2015	2016	2017	2018
January	5,975.00	5,980.00	6,071.00	6,793.00	5,294.00	5,727.00
February	6,247.00	6,260.00	6,320.00	6,652.00	5,389.00	5,853.00
March	6,540.00	6,582.00	6,732.00	7,249.00	5,683.00	6,030.00
April	7,197.00	7,140.00	7,184.00	7,833.00	6,065.00	6,714.00
May	7,172.00	7,828.00	7,811.00	8,012.00	6,746.00	6,670.00
June	7,103.00	7,619.00	7,934.00	7,729.00	6,759.00	6,585.00
July	6,851.00	6,850.00	7,396.00	7,421.00	6,380.00	6,315.00
August	6,669.00	7,172.00	7,485.00	7,372.00	6,553.00	6,644.00

September	6,616.00	7,000.00	7,582.00	7,603.00	6,436.00	6,478.00
October	6,545.00	7,006.00	7,364.00	7,269.00	6,332.00	6,697.00
November	6,684.00	6,878.00	7,292.00	6,815.00	6,395.00	6,514.00
December	6,634.00	6,485.00	6,797.00	6,794.00	5,881.00	6,239.00
Average	6,686.08	6,900.00	7,164.00	7,295.17	6,159.42	6,372.17

The table above presents the average demand of First Bay Power Corporation (FBPC) from year 2013 to year 2018. It can be seen that the average demand in year 2017 was minimum with an average of 6,159.42 kWh, while maximum in year 2016 with an average of 7,295.17 kWh.

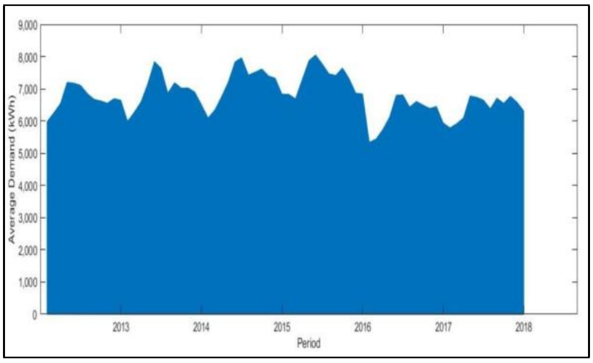

Figure 4.1.2 Average Demand (kWh) of FBPC (2013-2018)

The average demand of FBPC from year 2013 to 2018 is shown on Figure 4.1.2. On the load curve, it can be observed that the demand of FBPC spikes from mid of 2014 up to 2016. While, at the beginning of year 2017 the average demand suddenly decreases and varies up to year 2018.

Table 4.1.3: Average Demand (kWh) of IEC.

Months	2013	2014	2015	2016	2017	2018
January				2,790.93	2,897.47	3,172.99
February					2,805.38	3,662.48
March				2,985.94	2,992.96	3,461.43
April					3,335.20	3,595.99
May					3,725.75	4,083.84
June				3,447.24	3,794.56	3,902.71
July					3,527.70	3,663.48
August					3,282.95	3,707.15
Months	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
September				3,271.52	3,418.16	3,732.57
October				3,123.09	3,491.75	3,916.49
November				2,998.70	3,346.96	3,712.68
December					3,235.31	3,662.48
Average				3,102.90	3,328.99	3,691.98

Table 4.1.3 shows the average demand of IEC in kilo-watt hours from year 2013 to 2018. It can be observed from the table that the data from 2013 up to 2015 were missing while the data from 2016 were inadequate. These were due to the change in their management.

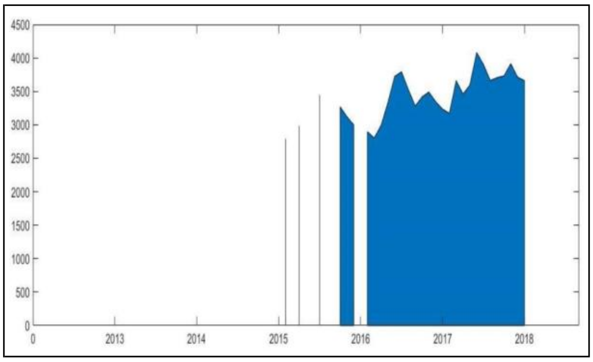

Figure 4.1.3 Average Demand (kWh)of IEC (2016-2018).

As seen from the figure, there was a growth in the average demand over the last two years. Thus, it can be interpreted that the average demand of IEC varies with time like the average demand of BATELEC II and FBPC.

Forecasted Demand of Various Electric Utilities in Year 2019 up to 2023 Forecasted Average Demand

The data gathered by the researchers from the utilities were used to predict their five-year average demand.

Table 4.4.4: Forecasted Average Demand (kWh) (BATELEC II).

Months	2019	2020	2021	2022	2023
January	117,648.55	123,770.78	125,182.78	136,091.61	137,560.11
February	120,196.06	122,301.24	127,440.96	138,223.35	144,956.08
March	123,199.79	123,052.97	127,119.67	140,136.80	148,366.12
April	135,203.88	135,099.59	137,548.63	151,728.05	151,914.17
May	135,671.90	143,818.40	145,631.88	156,758.94	169,221.04
June	126,054.73	143,046.03	150,176.82	156,511.74	166,781.87
July	128,334.78	123,788.46	142,711.98	150,054.28	161,064.35
August	128,334.78	134,667.03	142,049.16	150,672.89	161,309.49
September	124,450.80	143,468.24	143,468.24	154,222.83	161,998.22
October	129,643.72	141,929.82	142,182.75	148,719.00	160,979.91
November	126,611.45	143,569.36	143,569.36	147,272.31	155,663.35
December	130,453.83	137,980.49	137,980.49	146,823.96	150,019.29
Total	1,525,804.27	1,616,492.41	1,665,062.72	1,777,215.76	1,869,834.0

In Table 4.4.4, it can be observed that the predicted average demand of BATELEC II will vary in year 2019 to year 2023. It can also be seen that the lowest average demand in the Forecasted year will occur on the months of January and February, with the demand ranging approximately from 118,000 to 138,000 kWh. While the highest average demand will occur in the months of May and June with the demand ranging around 135,000 to 170,000 kWh. This can be noted that it may occur during summer season.

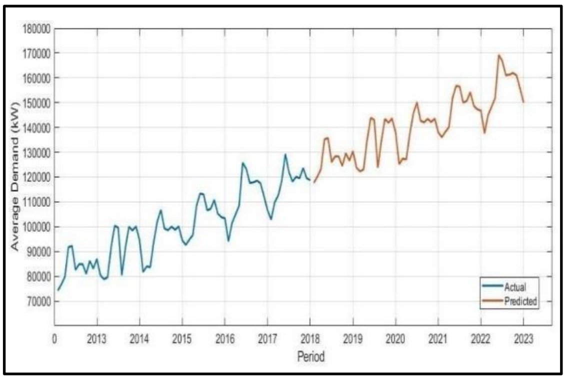

Figure 4.4.4 Forecasted Average Demand of BATELEC II (2019-2023)

The five-year Forecasted average demand of BATELEC II was based from the obtained data of the utility from year 2013 to 2018. Its average demand in year 2019 to 2023 will vary slowly with the demand ranging from 117,000 up to 170,000 kWh. Thus, it can be construed that the demand is directly proportional to the time. As time varies, average demand also does.

Table 4.4.5: Forecasted Average Demand (kWh) (FBPC).

Months	2019	2020	2021	2022	2023
January	6,482.00	6,488.00	6,578.00	7,300.00	5,801.00
February	6,754.00	6,768.00	6,827.00	7,159.00	5,896.00
March	7,048.00	7,089.00	7,239.00	7,756.00	6,190.00
April	7,704.00	7,647.00	7,691.00	8,340.00	6,572.00
May	7,679.00	8,335.00	8,318.00	8,519.00	7,253.00
June	7,610.00	8,126.00	8,441.00	8,236.00	7,266.00
July	7,358.00	7,358.00	7,903.00	7,928.00	6,887.00
August	7,175.00	7,679.00	7,992.00	7,879.00	7,060.00
September	7,123.00	7,507.00	8,089.00	8,110.00	6,943.00
October	7,052.00	7,513.00	7,871.00	7,776.00	6,839.00
November	7,191.00	7,385.00	7,799.00	7,322.00	6,902.00
December	7,141.00	6,992.00	7,304.00	7,301.00	6,388.00
Total	86,317.00	88,888.00	92,052.00	93,626.00	79,997.00

In Table 4.4.5, the Forecasted average demand of the FBPC from year 2019 to 2023 may range on about 6,500 to 8,500 kWh. It can be seen from the Forecasted year that the lowest average demand will occur on the months of January and February with the demand ranging approximately from 6,500 to 7,200 kWh. While the highest average demand will occur on the months of April, May and June with the demand ranging from 7,700 to 8,500 kWh.

Overall, the lowest average demand on the Forecasted year will occur on the month of

January 2023 with the demand of 5,801 kWh. While the highest average demand may occur on the month of May 2022 with the demand of 8,519 kWh.

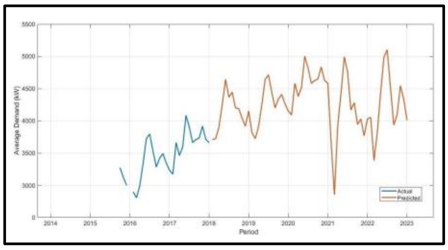

Figure 4.4.5 Forecasted Average Demand of FBPC (2019-2023).

Using load curve, the average load (from year 2013 to 2018) and the five-year Forecasted demand of FBPC was presented above. Like the latter, the blue line also represents the past energy usage of the FBPC while the orange line portrays the predicted average demand of the said utility.

In Figure 4.4.5, it can be observed that the Forecasted demand will have a large difference between the maximum and minimum trend line of demand. These variations of demand may be due to the decrease of average demand of FBPC from year 2017 to 2018.

Table 4.4.6: Forecasted Average Demand (kWh) (IEC)

Months	2019	2020	2021	2022	2023
January	3,708.81	3,815.35	4,090.87	3,658.61	4,051.96
February	3,723.26	3,723.26	4,580.36	2,851.71	3,385.42
March	3,903.82	3,910.84	4,379.31	3,918.27	3,818.75
April	4,253.08	4,253.08	4,513.87	4,433.64	4,440.66
May	4,643.63	4,643.63	5,001.72	4,992.89	4,985.87
June	4,365.12	4,712.44	4,820.59	4,755.67	5,102.99
July	4,445.58	4,445.58	4,581.36	4,167.07	4,514.39
August	4,200.83	4,200.83	4,625.03	4,281.29	3,933.97
September	4,189.40	4,336.04	4,650.45	3,944.65	4,091.29
October	4,040.97	4,409.63	4,834.37	4,029.54	4,544.84
November	3,916.58	4,264.84	4,630.56	3,768.15	4,338.43
December	4,153.19	4,153.19	4,580.36	4,028.80	4008.40
Total	49,544.27	50,868.71	55,288.85	48,830.29	51,216.97

In Table 4.4.6, the lowest average demand in the Forecasted year will occur on the months of January and February, with the demand ranging approximately from 2,900 to 3,700 kWh. While the highest average demand will occur in the months of May, June and July with the demand ranging around 4,400 to 5,000 kWh.

From the forecasted average demand of IEC, it can be observed that the highest forecasted demand will occur on the month of June 2023 with the demand of 5,102.99 kWh. On the other hand, the lowest forecasted demand may occur on the month of February 2022 with the demand of 2,851.71 kWh.

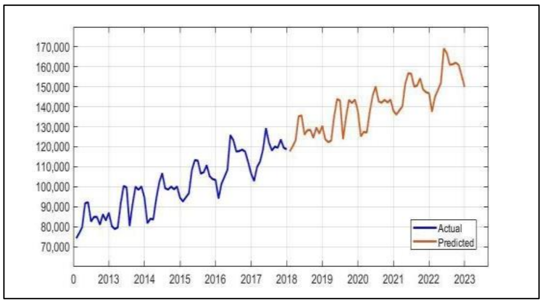

Figure 4.4.6: mForecasted Average Demand of IEC (2019-2023)

Figure 4.4.6 shows the past energy usage of IEC including the five-year Forecasted average demand of the said utility. Like the other load curve, the blue line also represents the past energy usage while the orange line portrays the predicted average demand of the said utility.

It can be seen from the load curve, that from year 2013 to 2015 there was no trend line formed. While in year 2016, the trend line has been broken. This was due to the unavailability of data from the past usage of the utility. Whereas it can be observed from Figure 4.4.6 that the predicted load drastically fluctuates. Thus, it can be interpreted that unavailability of data from the previous years will generally affect the forecasting of load. It can also be construed that the load will drop and may affect the load factor of the distribution utility.

The attainment of desired load shape objective can be achieved by the utilities by targeting specific end uses of the different customers.

Figure 4.7.1 shows the graph of the previous Average Demand (2013-2018) and the forecasted Average Demand (2019-2023) of BATELEC II.

Figure 4.7.1 BATELEC II Average Demand (2013-2023)

Figure 4.7.1 shows the past and the forecasted average demand for BATELEC II. It was clearly demonstrated that as time goes by pertained in year, the load demand also increases. Referring to the load curve, load shifting may be done in the system of BATELEC. During peak hours, other loads contributing to its peak would be shifted, or may be asked to operate during off-peak periods. As shown on Table 4.4.1.1, it acquired an above 75% load factor and through this load objective, it can gradually increase showing consistency of power supply.

Figure 4.7.2 shows the graph of the previous Average Demand (2013-2018) and the forecasted Average Demand (2019-2023) of FBPC.

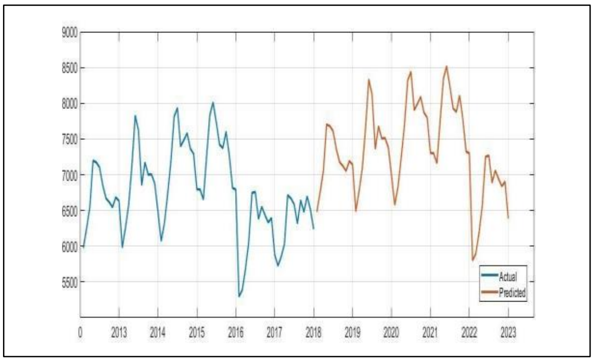

Figure 4.7.2 FBPC Average Demand (2013-2023)

From the figure above, the utility's load curve is varying thus it has a high difference between its minimum and maximum demand over time. On this case, peak clipping may be used to FBPC system. As shown in Table 4.4.1.2, during the year 2017 and 2018, its load factor drops to 74.74%, therefore utilizing this demand side management objective will improve the system of FBPC. The load contributing to its peak periods would shift its operation during off-peak periods.

Figure 4.7.3 shows the graph of the former Average Demand (2016-2018) and the forecasted Average Demand (2019-2023) of IEC.

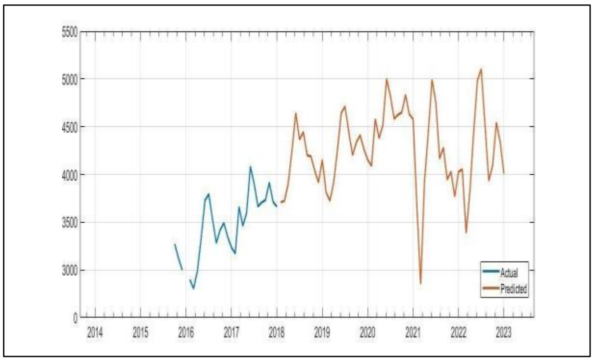

Figure 4.7.3 IEC Average Demand (2016-2023)

For Figure 4.7.3, the load shape objective that can be applied is also peak clipping. The graph shows a large variation of load on the past and forecasted demand of the utility. This load shape objective can be done by equal reduction of load within the consumers.

SUMMARY OF FINDINGS

1. Based on the load curve of BATELEC II, considering its past and future demand, the DSM program objective that can be done was load shifting. Since the load continuously increases as time goes by, shifting the energy usage can improve the load factor therefore stabilizing the operation of the system.

For FBPC and IEC, the load curve was varying. It has a big difference between the maximum and minimum demand both on its past and forecasted loads and peaks have been observed. DSM program objective that can be done was peak clipping. The demand which is contributing to the system's peak can shift their loads on off-peak periods thus giving both utilities a stable operation.

5. CONCLUSIONS

Determining the Demand Side Management program objective for BATELEC II, FBPC, and IEC helps for improvement of their system. Programs can be implemented by each distribution utility which can be subdivided into utility-controlled or consumer- controlled. When the program was implemented, it can help in stabilizing the operation of each system, therefore beneficial on the electrical power system in terms of load management done by an electrical distribution utility.

6. Recommendations

1. Analyzing other distribution utilities to know and predict the whole electrical demand of the province for the incoming years.
2. Gather the actual demand of each distribution utility to know its percentage error to the forecasted data.
3. Conducting a parallel study involving long-term forecasting of each distribution utility using methods which includes factors such as real time weather condition and temperature in determination of future demands.
4. Conducting a survey on different customers through verbal interaction to know how they manage and utilize their electrical demand within a certain period.

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