Application of DMAIC Methodology to Improve the Non-Technical Loss Reduction Process in Nueva Ecija II Electric Cooperative, Inc, Area 1

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Abstract: - Electrical energy losses in the distribution and transmission lines accounts to any lost energy generated from the transmission network of a power plant or electric substation down to the consumers. These losses can be a result of different parameters and the vast amounts are considered to occur in the primary and secondary distribution lines which are classified as technical (TLs) and non-technical losses. Nueva Ecija II Electric Cooperative, Inc, - Area 1 (NEECO II- Area 1) have identified different parameters that causes these non-technical losses which is considered as one of challenges that has been existing for years as the company has recorded inconsistencies in meeting the standard set. Reducing these identified losses not only can improve distribution efficiency in the power transmission lines but also can reduce the cost of electricity among its customers. Considering the electrical losses recorded by NEECO II Area 1 for 2018 and 2019 utilizing the Synergi Electric system that they are using, there is a significant amount of non-technical loss which impact the integrity of the total output being generated in the distribution system.

NEECO II has been practicing a standard and conventional process of managing the non-technical losses but has not been consistent in doing such as they do not have a standard documented procedure in place. This study is focused on developing a process of energy management using the DMAIC methodology (Define, Measure, Analyze, Improve and Control) to reduce non-technical losses identified in the NEECO areas and its distribution lines. With the gathered data, the researchers aim to develop recommend process that can help better identify, detect, and minimize the occurrence of these causes, thus reduces the overall non-technical losses in the distribution system.

Key Words: — ***Electrical energy, power plant, NEECO II, DMAIC methodology.***

I. INTRODUCTION

The occurrence of energy losses in any electric system is nothing new and considered one of the main causes of financial losses not only in the electric company but can certainly affect its stakeholders primarily the consumers. Technical losses such as conductor loss or load loss, core loss or no-load loss are totally inevitable and can surely be identified, calculated, and be fixed but one of the challenges that most electric companies like NEECO II Area 1 encounter is the existence of non-technical losses which constitute to electricity pilferage and theft such as illegal connection, meter tampering, meter error and billing irregularity.

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Among the most common and prevalent cases of electricity theft are meter tempering using magnetic materials and mechanical jerks that impedes the meters reading. Illegal connections which are unbridled in slums areas contributes to the big chunk on such loss. Metering inaccuracies and errors are also identified as one on the top list of non-technical loss contributors. Unmetered supply such as traffic lights, traffic signal and security cameras may not much of a big impact of the total loss but still can be on the list. The substantial amount of non-technical losses generated by the Synergi Electric system utilized by NEECO II shows that there has been significant amount of loss for the past 2 years indicated. These acts of dishonesty among members and consumers can certainly be detrimental not only to the financial condition of the electric utility provider and its stakeholders but also can cause scarcity of electricity. The rampant and irreverent illegal connections which are mostly cropping up in buildings, compound and slums can lead to accidents caused by electricity such as overloading, electric fire and explosions. The utility's financial loss represented by these non-technical losses are not inevitable. The financial implications, billing irregularities and inaccuracies caused by these losses are then passed on to the consumers which poses not only a challenge but a burden to the local communities in the area. Not only that they are being billed accurately for their just consumption but also must subsidized those who do not pay for their electricity services - intentional or not. For the year 2018 and 2019 alone, a total 47,005,149-kWh overall system loss (using an approximate residential consumer rate of Php 8.67 per KWH) and the non-technical losses associated with this has been distributed among its consumers and stakeholders making them dissatisfied and lose trust of the company's billing process. As part of the government's efforts to provide reasonable retail prices of electricity by setting annual loss caps and enhancing Performance Improvement Program, Republic Act 7832 otherwise known as the Anti-Pilferage of Electricity and Theft of Electric Transmission Lines/Materials Act was signed in 1994 [1]. Likewise, rural electric cooperatives (RECs) are aided by the Task Force on System Loss Reduction Program (SLRP) by recommending appropriate measures such as random ocular inspections of the alleged illegal connections (flying connections), routinary inspection of questionable consumptions of consumers based on the findings of NEECO II – Area 1 Billing section. In the aim to reduce the occurrence of non-technical losses and its cost implications, this study is focused primarily on not only to evaluate the prevailing non-technical losses in the coverage areas, improve the apprehension of identified electric pilferers in different NEECO areas, and develop a sustainable process improvement on energy management utilizing the DMAIC methodology. NEECO II Area 1 uses Synergi Electric, an electrical simulation software that generates and analyzes the overall data performance a power distribution system. It helps the electric utility primarily the engineers to monitor and evaluate the performance from the substations to the customer, thus helping them plan, investigate and optimize the full functionality of the entire network. This undertaking also considers the data generated by the NEECO's Synergi system covering the years 2018 to 2019 for the following distribution areas: Carranglan, Lupao, Talugtog, Science City of Munoz, Guimba, Sto. Domigo, Talavera, Aliaga, Quezon, and Licab.

II. Literature Review

There are wide variety of studies focusing on the reduction of non-technical losses in distribution network and each offers valuable perspectives and findings. [2] In Spain, a two-module framework and methodology was developed to reduce non-technical losses in Endesa Company based on the detection and inspection of consumers without any electricity consumption during a given period. Technology integration such as smart meter reading or power theft detection devices to easily detect any act of electricity theft have also been developed [4-5].[6] Detecting unauthorized consumption in the sense of non-technical losses is much easier by applying "Smart" meters and low voltage. In some studies, the behavioral aspects of consumers are taken into an account to detect possible fraud activities. In [7], an Extreme Learning Machine (ELM)-based approach was used to correlate the irregularities and abnormal behavioral kWh consumption of customers with NTL activities. [8] Theoretical study of the socio-economic and demographic factors can also be considered in identifying and analyzing the possible sources of NTLs. Collected data from the customer's daily and monthly consumption can also be used to monitor abnormalities which can be associated to potential electricity theft. [14] Data mining can be used as a tool for a more effective and targeted inspections focusing on the identified areas with suspected fraud. Using statistical modelling, focused areas of inspections are ranked based on importance.

Strategic implementation of detection and apprehension process of any act of electricity theft should also be given priority as this is a crucial step in eliminating the causes of NTL. The use of a renowned and structured process improvement such as Six Sigma DMAIC methodology has been proven to generate positive results through several studies and applications [9-10]. Process Improvement Methodology is one of the major focus of DMAIC that improves an already existing process. The idea of integrating both smart meter-reading device and data analysis based on the abnormal behaviors and irregularities of electric consumption in NTL detection is incorporated in the proposed process using DMAIC methodology.

III. Methodology

The Researchers Used And Explored On Descriptive Research Methodology Combining Process Documentation From Recent Studies And Implementing The DMAIC Methodology In Developing The Process Of Energy Management In NEECO 2

Area 1. As Defined, DMAIC Is A Problem-Solving Approach And Process Improvement Methodology Of Six Sigma That Is Used By Businesses In Improving And Optimize Current Processes, Identify, And Fix Errors To Produce Quality Output. [12] This Methodology Takes A Problem That Has Been Identified By The Organization And Utilizes A Set Of Tools And Techniques In A Logical Fashion To Arrive At A Sustainable Solution(S). DMAIC Stands For Define, Measure, Analyze, Improve and Control.

A. Application of DMAIC Methodology

Define Phase:

In the define phase, the problem that requires a solution needs to be identified and should end with a clear understanding of its scope. For the past few years, NEECO 2 Area 1 has been implementing a conventional energy management process in identifying non-technical losses and apprehending acts of electricity theft. This approach poses a challenge in consistently reducing the NTL as evident in the utility's generated monthly output for the years 2018 and 2019. Being able to strategically identify and detect the sources of these non-technical losses can absolutely minimize contributing factors, thus can eliminate the inconsistencies and discrepancies in the monthly distribution output. As the cooperative continue to use the Synergi Electric system which detects the overall system losses, it is still a stumbling block for the utility to identify the causes and sources of the non-technical loss in each substation as they, most of the time, rely on the reports of concerned citizens in apprehending acts of electric theft. In the year 2018 the total system loss is 23,050,823 kWh and in 2019 it recorded a 23,954,326-kWh system loss, technical and non-technical included. Although the recorded non-technical losses every year are being covered by the power purchased in the Wholesale Electricity Spot Market, it is undeniably evident that it has significant impact to the overall system loss and eliminating the contributing factors of NTL can positively impact distribution costs, thus can lead to a much more reasonable electric bill among consumers.

Measure Phase:

In this phase, current performances are measured, and the identified problem is quantified. [] The data gathered are based on the information shared by the Planning and Design Section of Technical Services Department and are based on the data generated by the Synergi Electric System. The given data below shows the recorded and tabulated overall monthly system losses of each coverage areas of NEECO II Area 1 for the year 2018 and 2019 [2].

Table.1. Monthly System Losses for 2018

NEECO II - AREA 1 System Loss for 2018								
MONTH	Talavera	Munoz	Quezon	Guimba	Pant	Aliaga	Lupao	Total
JAN	13.56	21.32	22.93	18.97	32.41	22.58	24.13	19.64
FEB	0.44	7.14	5.35	4.34	8.35	8.48	6.71	4.68
MAR	11.78	12.53	11.19	8.39	9.97	16.00	13.97	11.85
APR	10.01	16.37	15.45	7.96	12.48	14.44	12.34	11.96
MAY	8.64	13.87	13.01	9.19	10.34	14.54	14.34	11.39
JUN	6.21	6.26	13.21	4.27	6.56	9.97	9.84	7.32
JUL	5.86	18.56	0.00	6.04	18.62	10.73	13.49	10.71
AUG	5.81	16.20	0.00	4.93	5.32	8.00	10.81	8.84
SEP	9.74	23.33	0.00	9.51	20.09	19.46	17.05	15.16
OCT	6.15	22.52	22.32	5.42	8.90	15.63	14.80	12.05
NOV	2.46	8.24	12.00	10.04	16.62	11.24	12.96	9.12
DEC	(8.45)	(3.18)	5.20	(11.17)	(1.47)	(5.43)	(0.85)	-4.09
TOTAL/AVE.	6.51	14.17	11.92	6.55	12.14	12.23	12.08	9.85

Table.2. Monthly System Losses for 2019

NEECO II - AREA 1 System Loss for 2019								
MONTH	Talavera	Munoz	Quezon	Guimba	Pant	Aliaga	Lupao	Total
JAN	12.02	12.42	13.45	13.48	13.41	21.44	18.74	14.62
FEB	8.77	10.52	14.07	8.69	15.69	11.80	15.31	11.12
MAR	6.73	7.55	11.26	5.98	13.34	12.76	10.55	8.68
APR	4.53	10.61	10.76	12.17	12.38	10.94	10.61	9.34
MAY	14.45	15.33	17.17	11.76	21.54	18.22	19.83	15.77
JUN	10.09	3.67	8.66	8.94	17.11	14.38	9.54	9.39
JUL	4.84	6.70	11.09	9.55	16.99	7.95	13.53	8.60
AUG	1.73	0.91	6.55	3.48	3.45	2.95	4.75	3.23
SEP	10.44	9.25	16.54	12.02	22.14	15.05	16.26	13.25
OCT	7.59	8.22	13.72	9.03	8.89	10.88	12.13	10.05
NOV	6.41	5.12	13.40	11.10	20.67	8.79	11.63	9.67
DEC	(2.49)	1.77	1.66	(3.38)	(7.87)	(2.79)	(2.04)	-1.31
TOTAL/AVE.	7.38	7.51	11.42	8.64	13.34	11.12	11.68	9.38

Table.3. Overall Monthly System Losses for 2017 - 2019

MONTH	2017	2018	2019
JAN	19.68	19.64	14.62
FEB	6.39	4.68	11.12
MAR	9.92	11.85	8.68
APR	10.63	11.96	9.34
MAY	12.13	11.39	15.77
JUN	5.93	7.32	9.39
JUL	10.68	10.71	8.60
AUG	6.56	8.84	3.23
SEP	10.24	15.16	13.25
OCT	14.87	12.05	10.05
NOV	7.99	9.12	9.67
DEC	0.28	-4.09	-1.31
TOTAL/AVE.	9.58	9.85	9.38

The tables illustrated below show the tabulation of non-technical losses (in kWh) of the different substations of NEECO II Area 1 for the year 2018 and 2019. Non-technical losses in each substation were calculated by subtracting the calculated technical loss to the total system loss.

Table.4. Monthly Non-Technical Losses of Substations NEECO II Area 1 Year 2018

NON TECHNICAL LOSSES OF YEAR 2018												
SUBSTATION	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
TALAVERA	420,755.60	-388,235	304,378	172,946	64,824	-123,013	-57,586	-105,125	143,874	-61,272	-315,048	-615,987
MUNOZ	411,891	-4,704	166,282	303,408	231,714	-49,448	416,190	317,378	619,829	761,815	95,353	-272,604
QUEZON	248,562	-116,951	28,261	96,201	41,514	-2,552				-131,082	71,777	-107,920
GUIMBA	325,393	-328,109	-70,483	-221,109	-165,122	-418,314	-254,172	-328,068	-98,326	-306,440	-149,612	-974,616
ALIAGA	272,183	-82,821	129,008	60,993	35,374	-78,840	-15,796	-98,135	205,770	99,192	-31,492	-429,840
LUPAO	356,248	-113,389	107,325	30,505	93,378	-29,931	-1,751	-128,111	120,621	30,934	86,391	-741,880

Table.5. Monthly Non-Technical Losses of Substations in NEECO II Area 1 Year 2019

NON TECHNICAL LOSSES OF YEAR 2019												
SUBSTATION	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
TALAVERA	261,615	113,463	39,340	-249,107	488,356	150,882	-161,772	-261,379	142,892	-1,631	-50,943	-426,088
MUNOZ	159,643	106,838	35,204	85,508	289,387	-184,665	-26,589	-383,685	14,719	-40,206	-179,421	-308,500
QUEZON	56,461	88,249	42,189	-54,207	195,134	-126,874	1,584	-338,398	176,122	28,489	-5,175	-493,469
GUIMBA	62,014	-104,810	-185,720	-101,617	-41,250	-286,260	-163,766	-434,786	5,722	-163,280	-98,095	-752,239
ALIAGA	257,100	17,215	71,695	-116,613	186,441	29,608	-133,530	-270,869	114,134	-36,405	-83,647	-403,767
LUPAO	253,945	125,833	15,400	-71,587	289,537	-102,089	68,600	-231,442	155,860	13,963	-10,152	-514,025

Table.6. Average Non-Technical Losses of NEECO II Area 1 Substations

AVERAGE NON TECHNICAL LOSSES OF YEAR 2018 and 2019 (kWh)												
SUBSTATION	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
TALAVERA	341,185	-137,386	171,859	-38,080	276,590	13,934	-109,679	-183,252	143,383	-31,451	-182,995	-521,037
MUNOZ	285,767	51,067	100,743	194,458	260,551	-117,057	194,801	-33,153	317,274	360,804	-42,034	-290,552
QUEZON	152,512	-14,351	35,225	20,997	118,324	-64,713	1,584	-338,398	176,122	-51,296	33,301	-300,695
GUIMBA	193,704	-216,459	-128,102	-161,363	-103,186	-352,287	-208,969	-381,427	-46,302	-234,860	-123,854	-863,427
ALIAGA	264,642	-32,803	100,352	-27,810	110,908	-24,616	-74,663	-184,502	159,952	31,394	-57,569	-416,803
LUPAO	305,097	6,222	61,363	-20,541	191,458	-66,010	33,425	-179,777	138,241	22,448	38,120	-627,953

Analyze Phase:

Data collected is to be analyzed to determine the root cause of the problem and identify the source of variation. Considering all the gathered data as shown in the tables above, we have seen discrepancies and variation of data for the overall system loss and the non-technical loss. It is crucial that we has to ensure that an electric utility just like NEECO II Area 1, is aligned with system loss cap set by the governing agency and/or the regulatory body.

[13] The Energy Regulatory Commission (ERC) ResolutionNo.10, Series of 2018 has set the distribution loss caps for electric cooperatives as shown in the table below:

Table.7. Distribution Loss Caps for Electric Cooperatives

Year	Cluster 1	Cluster 2	Cluster 3
2018	12.00%	12.00%	12.00%
2019	12.00%	11.00%	11.00%
2020	12.00%	10.25%	10.00%
2021	12.00%	10.25%	9.00%
2022 onwards	12.00%	10.25%	8.25%

The system loss is calculated by getting the difference of the Total Sales in kWh and the Total Energy Purchased in kWh over the Total Energy Purchased.

System Loss (%)

$$= \frac{\textit{Total Energy Purchased } (kWh) - \textit{Total Sales } (kWh)}{\textit{Total Energy Purchased } (kWh)} \times 100$$

Considering the data illustrated in Table 5, for the year 2018 alone, NEECO II Area 1's overall system loss failed to consistently meet the 12% loss cap set by the ERC for Cluster 2 for 3 months – January, September and October. For the year 2019, with the set cap of 11%, the electric utility failed to meet the standard for four months – January, February, May, and September. NEECO II Area 1 may have met the system loss cap for the entire year, but it can consistently meet the set cap every month, that can assure a more productive output every year. For the average non-technical losses (2018 and 2019), January, March and May have been identified to be the months with the highest amount of non-technical losses measured in kWh as shown in Table 6 making Talavera, Lupao, and Munoz substations as the top contributors of these non-technical losses. These three areas can be the primary focus of the established and recommended energy management process.

Improve Phase:

In the aim to efficiently manage energy by reducing the non-technical losses in the distribution network by effectively monitoring and minimizing the identified contributing factors in the focused areas, the researchers would like to propose an improved management process that can be implemented by NEECO II Area 1.

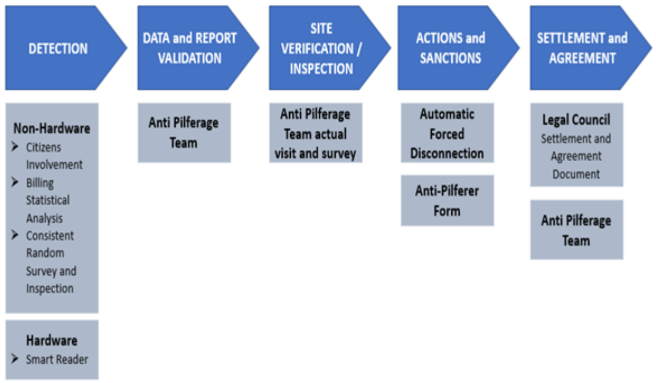

Fig.1. Proposed Energy Management Process of NTL

Detection Process: The most crucial part of the process is detection. It is indeed a challenge for electric utilities to detect the exact source of all non-technical losses. Different electric utilities implement different ways of detecting any act of pilferages or electric theft and other NTL contributors. The integration and utilization of hardware solutions such as the installation of specific devices like meters with tampering sensors and RFID devices can certainly boost the detection processes thus increasing the chances of reducing the NTLs. [14] Utilities from developed countries such as ENEL, an Italian multinational manufacturer and distributor of electricity and gas, integrated the use of smart meter-based infrastructure for minimize NTL in their coverage areas which improved their theft detection rate from 5% to 50%. The significant results of the smart meters installation have paved the way to new perspectives of developing a more advanced techniques of NTL detection. Non hardware solutions focus on NTL detection techniques using theoretical study by analyzing different factors and available parameters that constitute to the occurrence of NTL in a specific area such as population, geographical area, records on existing identified NTL zones and statistical techniques. Improving the detection process by not just merely relying on the reports or allegations from concerned citizens but implementing consistent statistical analysis of consumer electric consumption based on their monthly electric bill can help identify potential pilferers or any factors that cause non-technical losses. Billing Department should be able to provide monthly report to Pilferage Apprehension Team of all consumers, residential and commercial, with significant increase or decrease of electric consumption. Consistent random inspections and surveys focusing on the areas with the most instances of electric bill variation can also help identify potential pilferer and eliminate factors such as unmetered load and flying connections. Identifying the areas with the greatest number of pilferage cases and careful study of their socio-economic status can help in the detection process. The integration of smart reader in the detection process may lead to a significant boost in identifying and apprehending electric theft in any form should be considered by NEECO 2 Area 1 despite of its high equipment cost implications.

Data and Report Validation: Validation of data and reports is another critical task to be conducted by the assigned Anti Pilferage Team or Special Energy Recovery Group (Apprehension Group). All information that was gathered from any source should be handled with utmost sense of urgency and in-depth analysis. All reported act of pilferages or electric theft from stakeholders should be carefully assessed and immediately act on. In partnership with the billing department, all subscribers with significant variation of atleast +/- 30% of their normal consumption should be prioritized on regular and random inspections.

Site Verification and Inspection: Conducting random site inspection regularly can help reduce common factors that contribute to the occurrence of non-technical losses. After careful assessment and validation of the data given, the team should establish sets of schedules for random checking of all areas putting all reported and alleged pilferers and that of the data provided by the billing department. The use of statistical modelling techniques and data mining process can be a useful tool to target areas of suspicion.

Actions and Sanctions: As outlined in the Republic Act 7832, all apprehended pilferers based on the random inspections and investigations conducted by the Anti Pilferage Team will be immediately disconnected and will be asked to sign the Disconnection and Apprehension Report Form. Appropriate sanction for such act including fines or penalties as well as criminal case in accordance to RA 7832 will be discussed with the apprehended pilferer.

Settlement and Agreement: The pilferer may appeal and discuss with the Anti Pilferage Team together with the utility's legal councils any settlement relevant to the illegal action committed. Failure to comply with the agreed settlement or pilferer's rejection of the proposed agreement shall lead to the case being filed to court for formal and just hearing.

Control Phase:

In control phase, the goal is to be able to sustain the new process and set results to higher level. To achieve the expected goal of reducing the monthly non-technical losses in each substation of NEECO II Area 1, consistent monitoring plan and documentations of all results including the successes and challenges in each phase of the process should be done accordingly. All records must be kept by the process owner for future data analysis and institutionalized process improvements.

IV. Conclusions And Recommendations

Reducing non-technical losses is certainly one of the prevailing challenges that an electric utility has been facing and Nueva Ecija 2 Electric Cooperative – Area 1 is not an exemption. Segregation of loads conducted through Synergi Electric, a system used by NEECO II Area 1, shows the overall system loss (including technical loss) in each substation. For the years 2018 and 2019, it has been recorded that the substations with the highest amount of non-technical loss are Talavera, Munoz, and Lupao. With its conventional approach of energy management process and non-technical loss detection, it is in no doubt that they have been challenged in consistently keeping their monthly system loss within the set cap of ERC. With this, the proponents would like to propose the improved energy management process that can help identify and apprehend factors such as unmetered loads, billing errors and acts of electric theft in any form such as flying connections and meter tampering. Detection process has been improved as this is the most crucial part of the process. Aside for merely relying on the reports of concerned citizens, integrating the reports from the Billing section of all consumers with significant discrepancies in their electric consumption and their bill (+/- 30% tolerance) and the intensive data analysis of the Anti-Pilferage team, we can certainly expect positive results in achieving the goals of apprehending pilferers and correcting meter-related factors. The use of smart meters can certainly boost the detection process especially in those areas with the greatest number of recorded NTL. Consistent random survey and inspection of the focused areas can also help in ensuring that any attempt of unlawful act is minimized. Obtaining a reduction of atleast 30% on the existing NTL can absolutely impact not only the utility's entire distribution network but most importantly the consumers. The process is proposed to be implemented and monitoring as well as keeping records of the results in each phase of the process is highly recommended for data analysis and continuous improvement.

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