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Distribution Loss Analysis of NEA, Nepal

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Abstract: *Nepal Electricity Authority (NEA) is facing the problems in supply chain of electricity that causes the loss of energy which results in loss of economy. NEA has planned to extend the distribution network throughout the country so that every household can have access of Electrical Energy (EE) by 2023. NEA is also working in the sector of maximizing the sales in order to increase its revenue. In order to achieve such goals NEA must enhance its distribution system infrastructure. In this article, distribution losses are to be analyzed for enhancing and upgradation of existing electrical network if any. Some of the electrical components that cause electrical loss in distribution sector are also to be analyzed. This helps on determination of causes of losses. As NEA is importing electrical energy from India, consumer's sales energy should be analyzed. At present calibration of area specific electricity consumption pattern that too on Time of Day (TOD) basis is not possible. This research paper will determine the process that helps in identifying area specific consumption pattern thus aid operators in laying reliable supply chain infrastructure to meet the demand of electricity. Electrical loss to be minimized by enhancing distribution network as per consumer demand.*

Keywords: NEA, EE, Distribution System, Electrical Network, Electrical Loss, TOD

I. INTRODUCTION

NEA performs its work in distribution sector by manual approach for meter reading, maintaining the record of received and sales energy in sub-station in hand written log book which contains the information like incoming energy and outgoing energy as well as tripping occurrence of feeder at daily basis. NEA does the physical patrolling to identify the loss prone area and performs loss reduction control activities in those areas physically.

Loss energy calculation as well as spill energy calculation is still performed on the basis of manual calculation. No such automation by using ICT tools for doing all these works. So that it can be said that there may be data accuracy issues. Thus NEA must require the ICT tools to perform these tasks for data accuracy. Then only we can identify the actual problems regarding supply and demand of electricity. Once the real problem is identified in the field, NEA will resolve the problem with less effort in less time.

Line tripping occurrence causes the decrease in sales that may affect the revenues of NEA. Tripping is basically happened by improper sizing of conductor, overloading of transformer, asystematic increment of distribution line length without caring the feeder capacity. Phase unbalancing and lack in preventive maintenance of transformer, may also cause line tripping. Phase unbalancing is caused by unbalanced meter connection with pole wires. When tripping occurs frequently and transformers got burnt then only NEA starts identifying the causes of tripping by sending the concerned employee at the field. For this also no such ICT tools are used.

Billions of rupees are invested by NEA for manual support and maintenance in all distribution sectors every year. NEA can save that much time and money with less investment and less time if there will be use of ICT tools such as AMR, MDM and GIS mapping of field asset of distribution network sector.

In NEA, distribution losses are calculated by subtracting the sales unit from received unit where sales unit acquired from meter reading data and received unit acquired from distribution feeder. If difference between received unit and sales unit is positive then there will be loss.

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II. METHODOLOGY

This section is for electrical loss analysis of distribution sector of electrical utility in Nepal. This describes the various types of losses and its causes. Loss analysis as well as loss calculation is done herewith.

Supply chain consists of major components like supply, production and demand. So to make it robust system, one should know about its existing infrastructure and then to figure out its pros and cons, apply the suitable tools that can identify the bottlenecks in the supply system [1].

There are the consideration of two cases of power flow analysis. One is for peak time supply and normal time supply. In order to minimize the technical losses of distribution network, one has to reconfigure the feeder as well as replacement of inappropriate size of conductors used for distribution lines. Voltage profile can be improved by adjustments of transformer tap settings and feeder sectionalization with power supply from nearest substation. Undersized conductor should also be upgraded by higher sized conductor for voltage improvement if line length increases. Tap setting of transformer should also be changed at higher side of voltage. As voltage profile keeps important in power quality issues [2].

According to [8], the amount of energy transmitted might not be equal to the energy distributed to the consumers for sale. Thus the difference between the energy received from feeder and hence distributed to the consumer for sale is the loss unit. Accordingly the loss unit as well as loss percentage can be calculated as follows:

2.1 Loss Calculation

Energy Loss = Energy Received – Energy Consumed or Sales

Energy Loss % = [Energy Loss / Energy Received] x 100

This methodology is based up on data mining tools that uses decision tree model of machine learning algorithm.

If ED is positive then it is said to be Energy Loss

Else it is said to be Energy Gained

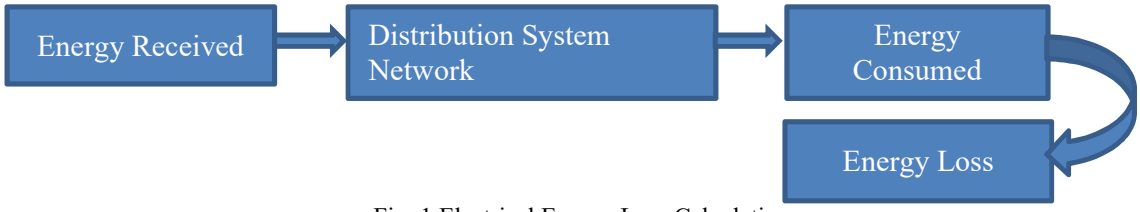

Fig: 1 Electrical Energy Loss Calculations

From this figure, it can be understood that received unit is read from feeder which is then distributed to the distribution network. The received energy is then consumed by the consumer which is treated as sales unit. Difference between received unit and sales unit if positive then it is said to be loss unit else it is said to be gained unit.

III. MODELING AND ANALYSIS

3.1 Electricity Distribution Loss Analysis

Some issues regarding losses in electrical power system are heating of electrical equipment, effects of parasitic elements, skin effects, iron, copper used in transformers while current flows in electricity distribution network. Besides these issues chances of non-technical losses are also caused by theft of electricity (by hooking on ACSR conductor connected with poles), meter tampering, chautara meter reading (i.e, by seating at one place meter reading is carried out by meter reader), irregular bush cutting etc. In appropriate size and type of conductor, transformer size and its acentric installation are also major factors of causing technical losses [3].

There are basically two types of electrical power losses:

a) Technical Loss

Technical loss is occurred by scattering of electrical energy through the elements used in the equipment such as conductors, resistors and magnetic losses in transformers. Due to the improper line length, size and type of conductor used in distribution sector, transformer placement without considering load center and its size with respect to secondary load in distribution line. The major factors of technical loss may be of phase unbalancing, inappropriate size and type of

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conductor, improper feeder line length, overloading of transformer and low power factor. Some of the factors are as described as here under:

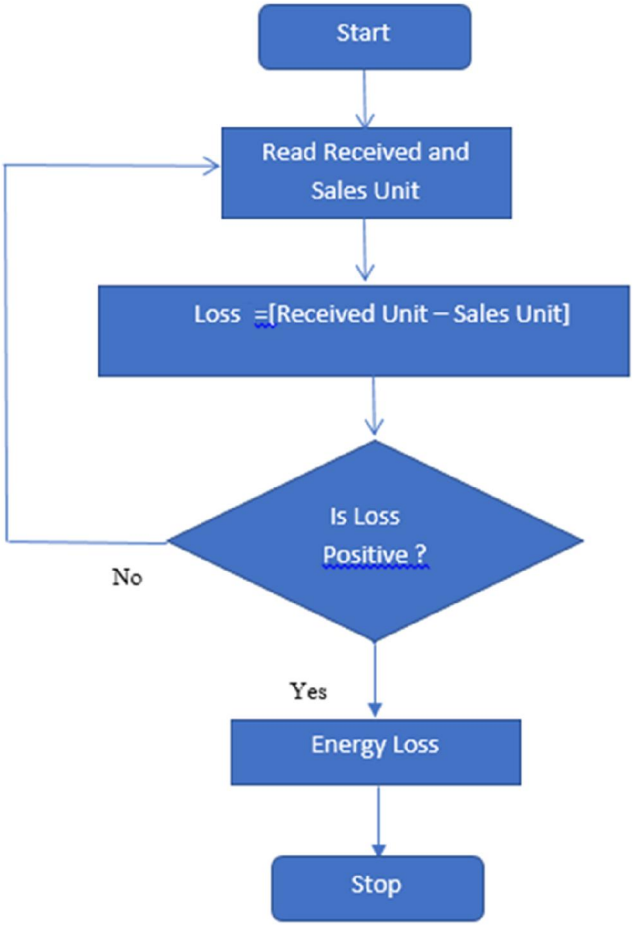

Figure 2: Flowchart of Distribution loss calculation

1. **Three phase unbalancing:** In three phases LT distribution lines, there are four wires R, Y, B and Neutral. If R, Y & B wires is having the phase connections equally distributed then it is said to be phase balanced else it is said to be phase unbalanced. For example, if R, Y and B is having connections of 2 each then phases are balanced with load. If R is having connections of 2, Y is having connections of 3 and B is having connections of 4 then phases are unbalanced with load and henceit caused three phases unbalancing that causes technical losses in distribution network.
2. **Size and type of Conductor:** In LT distribution lines, the size and type of conductor keeps meaning of losses. Inappropriate size of conductor causes line loss as per formula power loss = I2R and R =ℓ l/A. As conductor is carrying current this must be capable of bearing such load otherwise conductor may be burnt out that disturbs the distribution line thus results economy loss of electrical utility. That means longer the line length higher the cross sectional area of conductor otherwise it fails to carry the load. Type of conductor is also very important as resistivity varies from type of conductor. Higher the resistivity means higher the conductivity.
3. **Transformer overloading:** This condition arose when transformer is unable to supply the load as per demand from secondary side. That means transformer capacity is lower than the demand load. This situation also arises if transformer is installed at such location which is not load centric.
4. **Power factor:** This is also very important factor for causing loss. Higher the power factors lower the loss and vice versa. As power loss is directly proportional to square of the current flow in the network is more, obviously there will be loss of energy. So the loss can also be minimized by increasing the power factor. PF= Real

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Power/Apparent Power i.e., Power consumed / Power supplied [8]

b) Non-technical loss: Loss is caused non-technically due to the following major factors.

1. **Chautara meter reading:** Meter reading is done by sitting at one place and reading is done for all consumers. Such reading can't provide the real sales unit that result in loss of unit. This causes miss billing of energy sales
2. **Faulty meter: -** This device is unable provide the real consumptions of consumer. Thus it results in loss of unit.
3. **Unmetered supply:** No meter is connected at consumer end thus it becomes difficult to get actual consumed unit of consumer. So, it also causes loss of units.
4. **Irregular bush cutting:** It causes current leakage which results in loss of unit.
5. **Energy theft:** Unauthorized approach of consuming electricity is treated as energy theft. This is happened by meter bypassing, meter tampering, hooking etc.
6. **Untrained manpower work on site:** Untrained manpower don't know the network characteristics and do the support by hit and trial basis that may cause the line faults which results in sometimes huge loss.

Using this methodology, one can analyze the energy loss caused by some of the factors mentioned in block diagram. After analyzing of energy loss, supply chain management could be made optimal. Once the supply chain is optimized loss can also be minimized.

For electrical energy loss analysis, we have to consider at least of following factors:

1. Line Length
2. Conductor
3. Distribution Transformer
4. Meter Connection
5. Meter Reading Approach
6. Energy Theft

The following block diagram shows the electrical loss analysis:

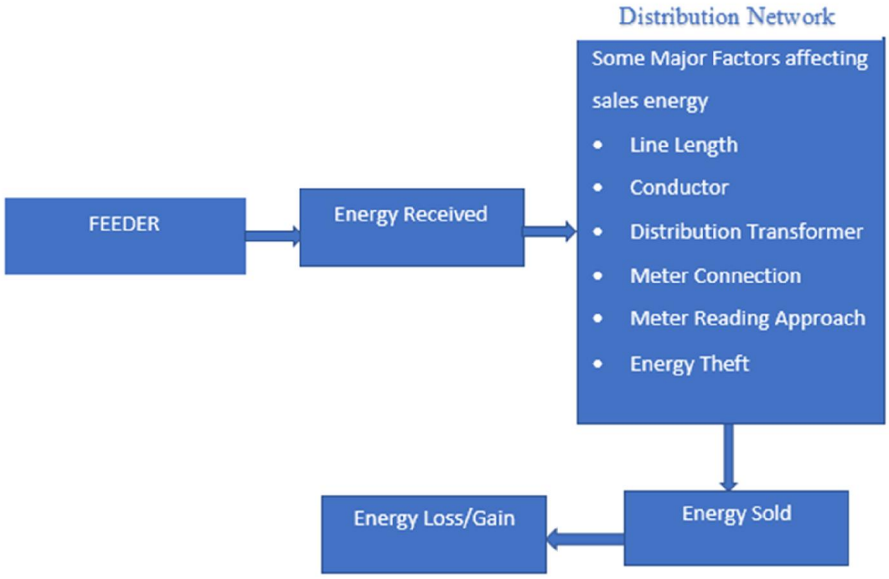

Fig 3: Block diagram of Electrical Energy Loss Analysis

Line Length: - This is the feeder's line length that describes the distribution distance for which the distribution line is drawn from the sub-station/feeder to cover the electricity consumer living place. This distance should not exceed the capacity of the feeder.

Suppose that the capacity of the feeder is of 11 kV and its coverage distance is 11 kilometers then there must be the line length of such feeder should be of 11 kilometers only. If line length goes beyond the distance limit then there should be the chances of line faults and such feeder gets overloaded. Longer the line length may have longer the conductor carrying

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current gets heated as long as the current remains on it. Electrical energy is converted into heat energy that causes the electrical energy loss.

R =ℓ L/A, where ℓ represents resistivity of conductor

Conceptually, higher the resistivity higher is the resistance. Higher the length of conductor poses higher resistance. But higher the cross sectional area of conductor lower the resistance. Hence for higher resistance may impulse the heat energy also that can trip the feeder. Thus to decrease the line loss line length as well as resistivity of conductor must be lower and cross sectional area of conductor must be higher. This phenomenon emphasizes the conductor's type and size.

Q = I2Rt i.e., Resistive Loss

Conductor: One must focus on the type, resistivity & cross-sectional area of conductor as it is the major factors for causing the line loss.

R =ℓ L/A, where ℓ represents resistivity of conductor

Distribution Transformer: - This is also responsible for causing energy loss if it is not placed at center of load, having phase balancing issues etc. More number of transformers may increase the technical loss as they have iron loss, cupper loss, hysteresis loss etc. Thus there will be optimum number of transformer in distribution transformer.

Meter Connection: - This is such a component from where energy consumption is read out i.e., sales unit of concerned consumer. If it is not connected properly with the poles wired with balanced manner then it causes the energy losses due to phase unbalancing. For example, there are 9 consumers those are connected with wires of phases R, Y & B improperly means that R has 2 connections, Y has 3 connections and B has 4 connections then it is said to be phase unbalancing which causes transformer overloading even though transformer is capable of supplying the power to those areas.

Phase balancing means there should be the balanced connections of consumer meter in such a way that each phase is connected with equal load. For example, if there are 9 consumers to be connected then each phase R, Y & B are having 3 connections.

Sample Dataset					
Poles	Phases			Result	Total Consumers
	R	Y	B		
Pole 1	1	2	3	Unbalanced	6
Pole 2	1	1	1	Balanced	3
Pole 3	2	4	6	Unbalanced	12
Pole 4	6	4	5	Unbalanced	15
Pole 5	5	5	5	Balanced	15
Pole 6	3	3	2	Tolerable	8
Pole 7	4	5	4	Tolerable	13
Pole 8	3	3	4	Tolerable	10
Pole 9	2	5	3	Unbalanced	10
Pole 10	6	6	6	Balanced	18

Table1: Phase connectivity issues

Meter Reading Approach: - Meter reading process is very sensitive as it provides the sales unit which is further used to calculate the energy loss. If reading is accurate then only the sales will be correct otherwise there will be compromise in loss calculation which results in wrong decision whether distribution network needs to be upgraded or not. So that meter reading process should be automated in such a way that there should not be intervention of manual approach to read consumption unit of meter. NEA is currently doing the meter reading manually as well as using hand held meter reading device. Almost consumers of NEA is having conventional meter.

In NEA, meter reader reads the consumer meter as per route assigned for every user on monthly basis. For example, consider the following table for different consumers with different consumer numbers.

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S. No.	Consumer Name	Consumer Number	Route No. as Reading Date	MR Holidays in a month are
1	Raju	001.01.001	01	07,14,21,28
2	Mohan	001.02.001	02	
3	Ramesh	001.03.001	03	
4	Rita	001.04.001	04	
5	Sita	001.05.001	05	
6	Mahesh	001.06.001	06	
7	Gita	001.08.001	08	

Table 2: Consumer number details

Here, format of Consumer Number is Area.Rout.Consumer Number. First 3 digit represents Reading Areas, Second 2 digit represents Reading Date called as route and last 3 digit represents consumer serial numbers, this may also be of alphanumeric such as 001KA, 001KA1 etc. Meter Reader reads the consumer meters as per consumer numbers mentioned in the table. Maximum number of Meter Reading Areas may be of 999 in a Distribution Center, Maximum Routes may be of 28 in a month and Maximum number of consumers may be of 999 per route in a Distribution Center.

The consumer as Mahesh whose meter reading is done at 8th of every month as mentioned in table above, but we consider the monthly sales for calculation of energy loss against received unit from feeder meter. For this consumer 8 days remained unbilled and rests of the days are billed according to [5].

General practice of meter reading in Nepal is manual as well as using hand held device.

Data set as for general idea

S.No.	Meter Reading Approach	Sales Accuracy
1	Manual reading	Less
2	Using hand held device	Medium
3	Using ICT tools	High

Table 3: Meter reading approach

Solutions for acquiring the actual consumption unit from consumer meter are usage of smart meter with AMI (Advance Metering Infrastructure) & MDM (Meter Data Management) features facilitated with IoT (Internet of Things), replacement of faulty meters, smart meter for reading consumer meters etc. [5].

MDM manages and stores the reading data to be transmitted as per user request. It also validates the reading data as well as outage events if any.

Energy Theft: - It is the critical issues for management for minimizing the energy loss. It increases the overhead costs for prevention of such thefts being happened in some reading areas.

Electrical energy stealers are those who are stealing the electrical energy that increases the power consumption in a region. Electrical utility has to patrol such energy theft areas to minimize such theft activities also take action against them by applying legal penalties. Such theft activities also cause for transformer overloading even they are set up for fulfilling the energy demand of such areas. The transformer which is being overloaded as such consequently may reduce its lifetime [6].

Solutions for minimizing energy thefts are routine-based patrolling of theft prone areas, proper sealing of meters, implementation of medium voltage distribution in theft prone areas, usage of ABC (Arrear Bundle Cable) cable in distribution network, usage of GIS tools for detection of theft activities etc.

S.No.	Theft behavior	Solution
1	Hooking	Usage of ABC cable
2	Meter tampering	Proper sealing

Table 4: Theft behaviors

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For analyzing the distribution loss, one has to analyze the weak points of the distribution line. As we know that there is constantly changing the load of distribution transformer during the operation of distribution network. Based upon the statistical data obtained through power flow, distribution network feeder can be identified for certain loss factors as it uses the severely aged branches, low power factor transfer with excessive power loss branches [7].

For solution point of view, one can do the maintenance of distribution line as follows:

- Replacement of old aging conductor,
- Replacement of bared conductor with cover one
- Increase the cross section of conductor

For solution point of view, one can do the maintenance of distribution transformer as follows:

- Replacement of old aging transformer
- Retrofitting of high loss transformer
- Usage of low technical loss transformer

IV. RESULTS AND DISCUSSION

4.1 Results

Tabular data of Distribution Centers (DC) with respect to loss analysis in percentages are as follows:

	Loss Values in Percentage			
Branch Name (Meter Used)	July	August	December	January
Baneshwar DC (Conventional Meter)	10.52	12.09	19.28	12.56
Maharajgunj DC (Smart Meter)	10.97	10.05	11.17	10.61

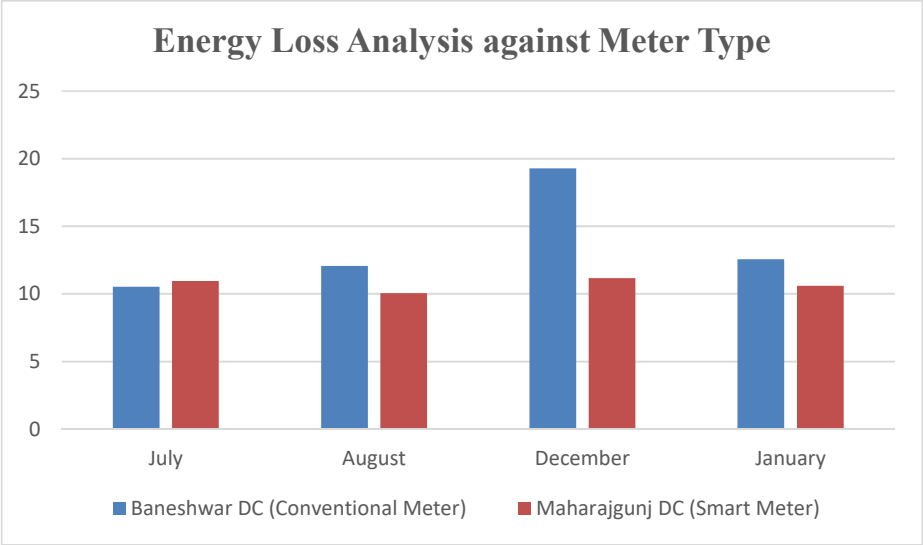

Chart 1: Distribution Centre Loss Analysis

In the above data sheet, there are two distribution centres namely Baneshwar DC & Maharajgunj DC. The data shown in table are of 2021/2022 Fiscal Year. These data are of loss percentage of the particular month mentioned over there in table. This chart represents the energy loss percentage of two distribution centres for both wet and dry season. Here seasonal loss of data are considered such as dry season includes month as Poush & Magh and wet season includes month as Shravan & Bhadra. Generally NEA considers six months as dry season and other six months as wet season. Dry season includes Marga, Poush, Magh, Falgun, Chaitra, Baisakh and wet season includes Jestha, Ashadh, Shravan, Bhadra, Ashoj, Kartik. NEA does such consideration for dry & wet season in Nepal.

Here Baneshwar DC uses conventional consumer meter for measuring the energy consumption where as Maharajgunj DC uses smart meter for measuring the energy consumption but having the similar distribution network situated in

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Kathmandu valley. The data says that Maharajgunj DC (Distribution Centre) which is using smart meter having the less loss as compared to Baneshwar DC. By these data it can be observed that energy loss can also be minimized by using ICT tools like smart meter instead of using conventional meter.

4.2 Discussion

The following block diagram represents two different meter reading approaches. One is done manually by meter reader and other is done by using smart meter. As manual approach of meter reading produces inaccurate sales as compared to smart meter approach.

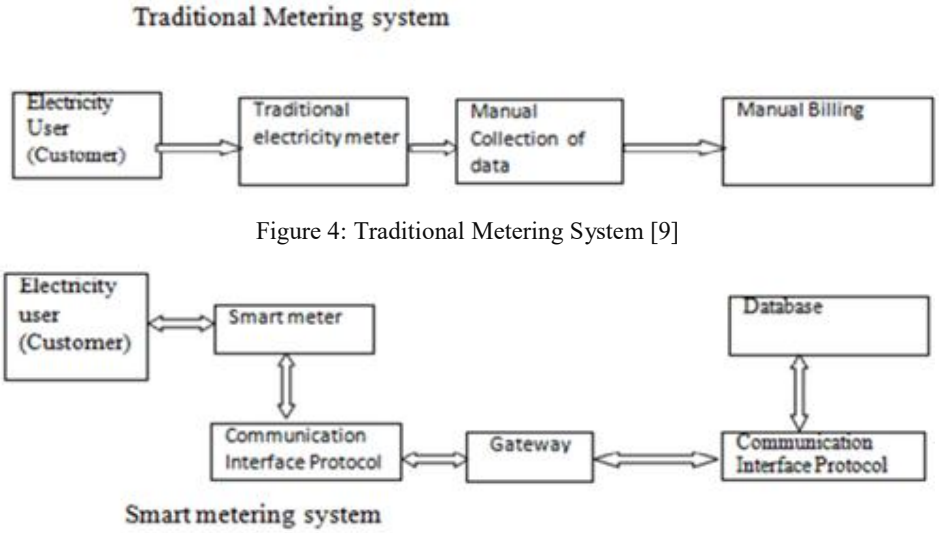

Figure 4: Traditional Metering System [9]

Figure 5: Smart Metering Systems [9].

In context of Nepal, manual meter reading approach may sometimes lead to chautara reading means that seating in one place doing reading of all the consumer meters of particular reading area. Such manual reading approach may result in accurate sales energy thus result in loss of revenue. Therefore it is suggested that electrical utility of Nepal namely NEA should replace all the traditional meters by smart meter and do the meter reading automatically by using ICT tools like smart metering system as shown in Figure 5.

There are basically two major types of losses such as technical and non-technical loss.

Factors of technical losses could be transformer, conductor, power factor, line length, phase unbalancing etc.

- **Transformer: -** Installation of transformer must be of load centric. It should not be overloaded. Aging factors must be considered.
- **Conductor: -** It must be of appropriate size and type that can match with the load lines. Longer the line length higher the cross sectional area of conductor otherwise it causes the energy loss.
- **Power factor: -** It must be optimal otherwise overloading condition arises.
- **Phase unbalancing:** - Consumer meters connections with the phases such as R, Y & B must be balanced. For example: R, Y & B must have the equal number of meter connections otherwise phase unbalancing occurs that causes tripping which result in energy loss. Factors of non-technical losses could be improper meter reading, hooking, unmetered supply, irregular bush cutting, faulty meters etc.
- **Improper Reading: -** This is done by chautara reading practice that means meter reading is carried out by meter reader by sitting in one place. For actual reading one can use the ICT tools like smart meter instead of using conventional meter. This meter must be of IoT based so that one can do the instant meter reading.
- **Hooking: -** This is the energy theft mechanism practiced by the unauthorized consumer those are consuming the electricity illegally. This can be controlled by using ABC (Aerial Bundled Conductor) cable instead of using ACSR (Aluminum Conductor Steel Reinforced) conductor.
- **Unmetered supply: -** This is the supply of electrical energy without using unit measurement components like

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meter.

- **Irregular bush cutting: -** There should be a regular bush cutting scheme otherwise current leaks through bushes which result in loss of energy.
- **Billed energy:** This is the energy consumed legally by authorized consumer with provided lines of connections.
- **Unbilled energy:** This is also an energy consumed generally happened by non-technical losses occurrences due to hooking i.e., unauthorized access to the lines, leakage of current etc.

Loss calculation is done by using the formula which is experienced in Nepal Electricity Authority is hereunder:

Loss Unit = Received Unit – Sales Unit

Loss % = [Loss Unit/Received Unit] x100

Where received unit is obtained from distribution feeder and sales unit is obtained from meter reading done by meter reader.

V. CONCLUSION

With the study of various tools and technique, it is concluded that one has to do the actual reading of energy meter regularly by using smart meter featured with ICT tools like AMI (Advanced Metering Infrastructure) and MDM (Meter Data Management). This tool can store and retrieved the meter reading data as and when required by the management. If there is actual meter reading then only actual sales can be obtained and analyzed the real loss unit of the particular distribution center. The result shown above proves that smart meter can minimize the loss as compared to conventional meter. For better analysis of loss causing factors one has to do the followings.

- Use of smart meter.
- GIS Mapping of the entire distribution network that consists of substation, feeder, transformer, poles, conductor, consumer meter

Without using ICT tools like smart meter and GIS Application in distribution network of NEA it will be difficult to minimize the energy loss as well as troubleshooting time of electricity network fault.

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