Blackouts in Nepal
&
Dynamic pricing

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FOREWORD

First of all I would like to give huge credit to my thesis supervisor Prof. Earling Moxnes for his great help and suggestion on the process of writing this thesis and I also would like to thank whole system dynamic group and my family, they have also huge contribution to complete this thesis.

ABSTRACT

This paper mainly analyzes the power shortage in Nepal by using the system dynamics (SD) tools. From the last ten years, Nepal has been facing the challenge of load shedding and it is increasing year by year because the demand of electricity is much higher than the generation and price of the electricity is fixed so the dynamic pricing on the Nepalese electricity market solves the blackout in the short time. It also increases the satisfaction of need of the consumers. All the data used in this thesis has been taken from the NEA annual report. By the use of dynamic pricing (DP) policy, the price of the electricity varies according to the demand of the electricity such as higher price during the peak hours and lower price in off hours. This is the best fit policy in the Nepalese electricity market to eradicate blackout.

However, without understanding the concept of dynamic pricing (DP) and how it's affect on demand and supply of power as well as the consumers satisfaction of needs. This thesis tries to address the issue by developing the system dynamics model on the basis of dynamic pricing in the electricity market of Nepal. And the conclusion is that the smart market pricing (SMP) policy able to balance the demand and supply of electricity with the help of price elasticity of demand in the Nepalese electricity market and it also able to increase the satisfaction of customers need.

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ABBREVIATIONS

NEA: - NEPAL ELECTRICITY AUTHORITY
GoN: - GOVERNMENT OF NEPAL
MW: - MEGA WATTS
KW: - KILO WATTS
MWH: - MEGA WATT HOURS
KWH: - KILO WATT HOURS
SFD: - STOCK AND FLOW DIAGRAM
CLD: - CAUSAL LOOP DIAGRAM
Ped: - PRICE ELASTICITY OF DEMAND
RTP: - REAL TIME PRICING
SD: - SYSTEM DYNAMICS
SMR: - SMART MARKET PRICING
DP: - DYNAMCI PRICING
IPP: - INTERNAL POWER PLANT
NPR: - NEPALESE RUPEES
ROR: - RUN OF RIVER TYPE
AMI: - ADVANCED METERING INTERFACE
AMR: - AUTOMATIC METER READING
DSO: - DISTRIBUTION SYSTEM OPERATOR
NOK: - NORWEGIAN KRONER

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1. INTRODUCTION

1.1 Problem

Nepal experiences frequent blackouts also called load shedding in the electricity market. Blackouts, typically last 13 hours in a day and maximum of 17 hours in the extremely dry season. The obvious reason is that the production of electricity is very much lower than the demand while the demand for electricity has been increasing and the production of electricity has nearly stagnated. This is a great problem for Nepal's economy. Business, industries, agriculture and households all these sectors has been facing the blackouts challenge and because of the load shedding they are not able to use their full capacity on own sectors. To minimize the problems for themselves, many electricity consumers end up with costly alternatives such as batteries and gasoline generators. Nepal is blessed with significant hydropower resources. Theoretically Nepal's hydropower potential has been estimated to be around 84000 Mega Watts, of which 43000MW has been identified as technically and economically viable. Currently the country has 753MW installed hydropower capacity (International Hydropower Association, IHA). During the peak hours, Nepal saw the electricity consumption growth rate of 7.56 percent in 2016 and integrated peak power demand stood 1444.10 MW, with 691 MW load shedding of them 2175.04 Gwh electricity imported from India (NEA, 2016/17) and rest of the electricity fulfilled through load shedding. This is clearly a huge problem in the electricity market of Nepal. Nepal electricity authority (NEA), the sole responsible organization in Nepal for the production and distribution of electricity has promised to eradicate the load shedding in coming five years. Since the problem has persisted over a long time period so there are good reason to take a fresh look at old and new policies.

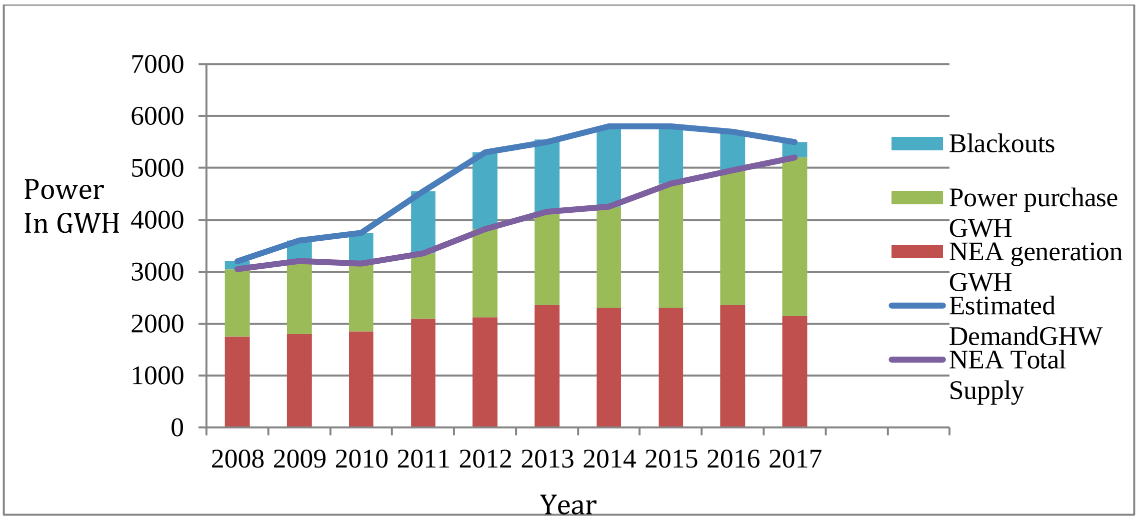

Figure 1:- Total energy Supply and Energy Demand (Source: - NEA report 2016/17)

Figure 1 clearly shows that the condition of electricity market in Nepal from the 2008 to 2017, the available energy in 2008 was 3200 Gwh and almost double in 2017 with 6300 Gwh. The generation of electricity almost remain constant during whole period but the peak demand electricity increasing every year but at the mid of the 2016 the GoN and NEA able to buy electricity from India to maintain the peak hour. In the last one decade the electricity imported from India nearly increases six times greater than 2008.

1.2 Hypothesis

The hypothesis of this study is that the main reason of power cuts in Nepal is the fixed pricing policy of electricity, which is imposed by the NEA. If the price of electricity is fixed then customers have no incentives to adjust demand and that creates the huge gap between demand and supply of electricity so the price should be varying according to demand and that policy can make equilibrium between demand and supply in the short run. The varying pricing policy attract the investors to invest their money on hydro power plant and solar power project and that generates more electricity in the future so the variable price in the short run ensure that the balance between demand and supply of electricity in Nepalese market in the long run.

1.3 Analysis

By analyzing the hypothesis, to introduce a new policy ‘smart market’ where the price of electricity depend on the basis of demand that mean when the demand increases the price also increase vice versa. Instead of old fixed pricing policy, the new dynamic pricing policy somehow able to manage the demand and supply of electricity in Nepal because it definitely changes the electricity utilization behavior of the customers. It has two different prices like high demand hour price which is known as peak hour price and low demand hour price rate also called off hour price. So the NEA earning will be high and it will motivate private sectors also to invest money on electricity generation. The NEA introduced the blackouts in 2006 by cutting the electricity 1 hour per day and promised to eradicate this problem in coming 5 years through investment in hydro power and solar power. But the defective vision and short sighted policy of NEA and the government of Nepal could not solve the problem. They were not able to attract more investors in the electricity market of Nepal because there was neither profit nor security of investment. Previousy, Karanjit,Raunak, (2016) used the system dynamic method and model to study The Future of Nepalese Electricity Market through the Dynamic Pricing and he has mainly focused on the short term demand and supply equilibrium and consumer benefit but this thesis is concern not only short term solution of blackouts but also measured the satisfaction of customer's need and help to generate more electricity in the long term to eradicate the blackouts from the country. Barbara R.Alexander has written article about the dynamic pricing and smart market and mentioned the default service policies for residential customers in restructured energy markets and the implications of advanced metering and dynamic pricing policies for low income customers.

1.4 Policy

NEA has tried to increase the electricity tariff many times to control the demand of electricity but this policy is against the people's welfare and the government had to face strike every time when they want to increase electricity tariff. The moving price policy is the best policy for Nepalese market because it is not only help to fulfill the gap between demands and supply of electricity but also increases the customers' satisfaction of needs through utilization of electricity because this policy has determined the price of electricity according to the demand so the higher demand high price and similarly lower demand low price so the customers will be benefited by postponing their unimportant usages of electricity to the off hours.

1.5 Implementation

The varying pricing policy is in favor of welfare of the Nepalese people in the short run because less electricity users in the peak hours pay less money so this policy is better from the economic point of view and satisfaction of customers need by supplying electricity whenever they want. This policy gives choices to the customer and they can decide how to use electricity and how they can increase the satisfaction of needs by using electricity whether in the peak hours or off hours. Investors also make more profit by selling electricity in the peak hours and that encourages the investors invest more money to generate electricity. By using this policy there may be no blackouts in Nepal in the long run.

2. BACKGROUND AND LITERATURE REVIEW

2.1 Background

Nepal is a small South Asian landlocked country and it shares border with big countries such as China and India. The electricity crisis of this millennium began in 2006 but the Nepal saw the last electricity crisis of the last millennium in 1999 and with the commissioning of the khimti Hydroelectric Project in 2000, there was no load shedding in Nepal till 2005(Ratna Sansar Shrestha,2010). The NEA introduced the blackouts in 2006 by cutting the electricity 1 hour per day and promised to eradicate this problem in coming 5 years through investment in hydro power and solar power. But the defective vision and short sighted policy of NEA and the government of Nepal could not solve the problem. Nepal has huge potential of hydro power because of enormous water resource blow form the Himalayans and geophysical setting. Despite having such potential, nearly half of the Nepalese people still deprived of electricity and rest of them facing long hour's blackouts. The main cause of power shortage in Nepal is the imbalance of demand and supply of the electricity.

The annual peak demand of electricity is increasing year by year with average more than 10 percent, it was 1291.8 in 2015/16 and 1444.06 in 2016/17(NEA report). This situation has resulted negative impact on production and service sectors and overall development of the nation.

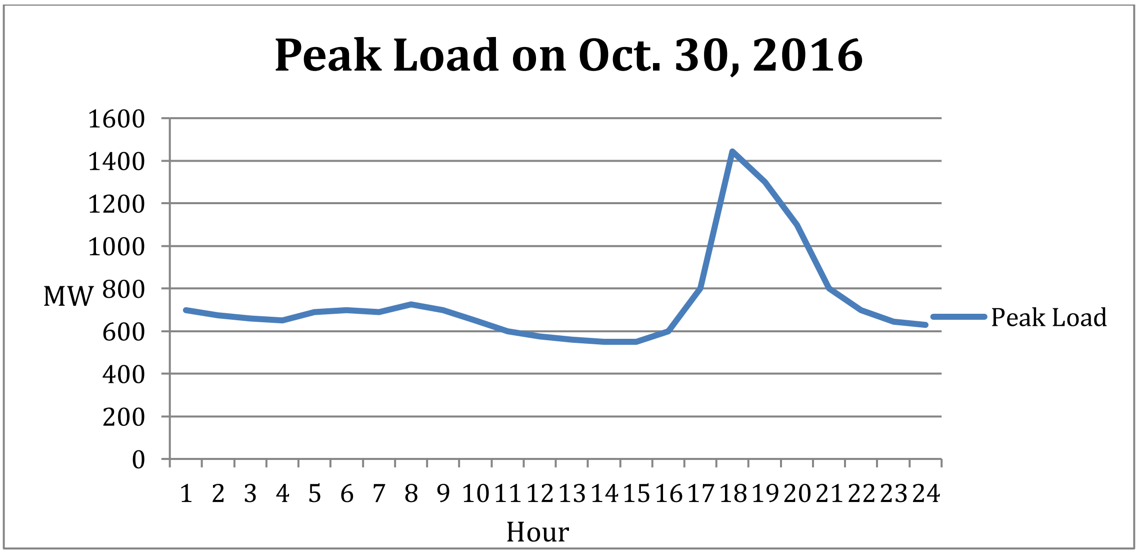

Figure 2:- Hourly System Load Curve on October 30, 2016 (Source: - NEA Report 2016/17)

Figure 2 provides the good overview of peak load curve electricity demand and how it leads to blackout in the country.

2.1 Literature Review

A lot of people have done research and published paper on the topic of dynamic pricing on the electricity market. This chapter deals with the literature, concerned & relevant to this study. This part of thesis is essential to know about the finding of other researchers which have conducted before & are appropriate to the study. Review of literature can be taken as means of the base to study. It provides guidelines ideas & many-more important information for every researcher. Normally a researcher can identify to which end the similar research has been conducted before & from which point should be conduct rest of it.

Mr.David Sundøy Haldorsen , Mr.Håkon Nikolai Løhren Heiestad and Mr.Nikolai Hoelgaard Weum-Andersen, 2016, they all have done combined research on the topic of '*Hydro Power in Nepal'* to submit the bachelor's thesis for the **Sogn og Fjordane University College** in 2016. The major findings of this thesis are as follows.

- Dry season
- System loss
- Load shedding (Blackout)
- Accessibility

Dry season has huge impact on the production of electricity in Nepal because all the hydro powers based on the river and in the dry season the volume of water is very low in the river so the storage type facility is needed to store.

System loss also another factors in Nepalese electricity market such as technical loss and non technical loss. Technical loss like resistance loss through distribution can be solved by replacing new and modern transmission and to solve the non technical loss needs more study and research.

Dry season, lack of storage type facility and system loss are the main reason behind load shedding (blackouts) in Nepal because NEA and GoN both are unable to solve the above problem. Load shedding will be eradicated if the supply of electricity is higher than the demand.

Geographically, Nepal is a landlocked country with mountains and Himalayan so it is not easy to access.

Raunak Karanjit, 2016, has done research on the topic of '*Dynamic Pricing and the Future of Nepalese Electricity Market*' to submit the master thesis to the **University of Bergen**. On this paper he used secondary data to analyze the load shedding problem through system dynamic model and theory such as dynamics pricing and how dynamics pricing balance the demand and supply of electricity in Nepalese electricity market. The main findings of this paper's are as follows.

- Dynamic pricing match the demand and supply of electricity in the short run to eradicate blackouts from the country.
- Dynamic pricing increases the total revenue because in the peak hours the price of electricity is higher than the normal hours.
- This policy has created an opportunity for others to invest money to generate electricity.
- The consumer utility is higher than before the use of this policy.

3. Model and experimental design

To explain the above problems the system dynamic model and theory should be used for the further simplicity. System dynamics theories have a lot of modern and computerize tools and technique to understand and solve the problem.

3.1 Stock and Flow Diagram (SFD) with dynamic pricing.

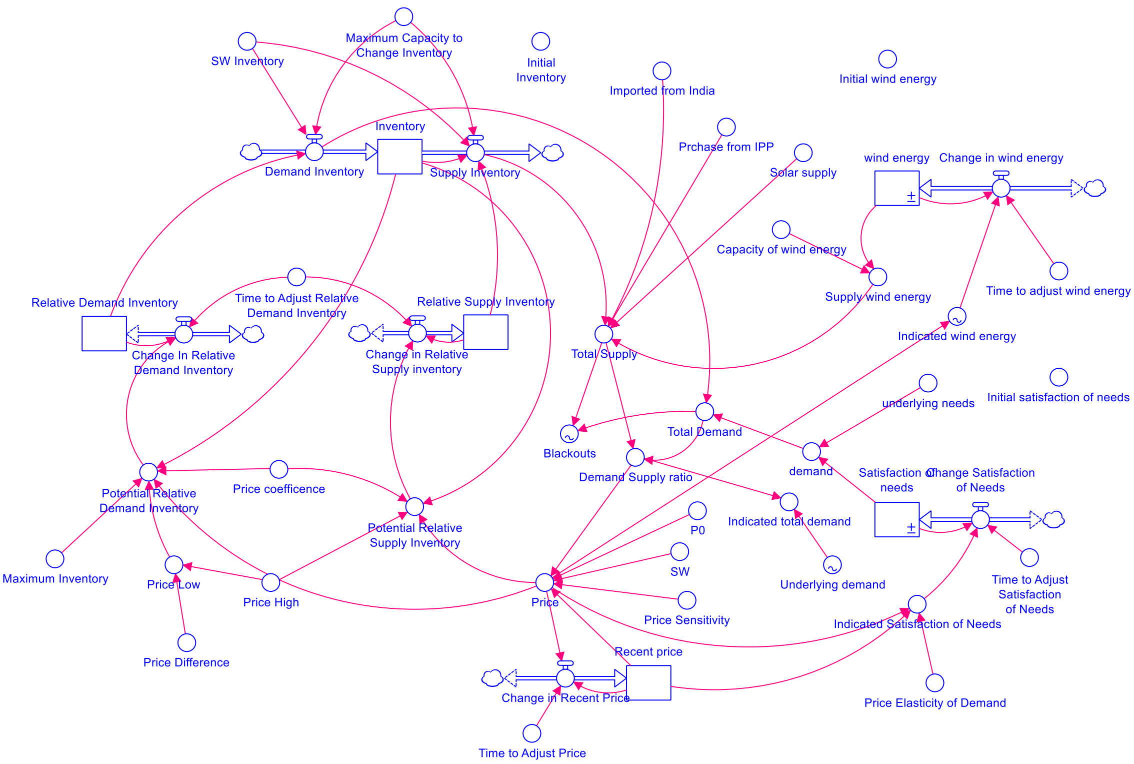

Figure 3:- Stock and Flow Diagram (SFD)

The above figure is the stock and flow diagram of dynamic pricing model and this model can be elaborated in a simplified manner as well.

Let, start with blackouts because it is the central point of this whole thesis.

$$Blackouts = Maximum\ (0, Total\ demand\text{-}\ Total\ supply)$$

The difference between total demand and total supply is the blackouts in other words if the demand is higher than the supply it creates gap between them and that is called blackouts, here blackouts cannot be negative so max function has been used to simplify the term blackouts.
Similarly,

*Demand Inventory = SW Inventory*Maximum Capacity to Change Inventory*Relative Demand Inventory*

Demand inventory is based on the actual data provided by the Nepal Electricity Authority (NEA, 2016) report.
So, the multiple of SW inventory, maximum capacity to change inventory and relative demand inventory is the actual demand inventory.

Change in Relative Demand Inventory = (Potential Relative Demand Inventory – Relative Demand Inventory)/ Time to Adjust Relative Demand

Like this change in relative demand inventory depends on the difference between potential relative demand and the relative demand and the divided by the adjustment time which is 10 minutes, that means, it takes ten minutes to change the relative demand inventory of this model.

Potential Relative Demand Inventory = IF Inventory<Maximum Inventory THEN MIN(1, MAX(0, (Price Low-Price)/2)) ELSE 0

Potential relative demand inventory determines by the inventory. If the inventory is lower than the maximum inventory then the potential relative demand inventory will be minimum 1 and maximum 0 or the difference between price low and price divided by 2 because potential relative demand inventory never be negative.

Price low = Price High - Price Difference

Price low is calculated by the difference between high price and price difference. Price high is the high price at the peak hour and the price difference is the gap between peak hour price and off hour price.

Price = Recent price(1+Price Sensitivity*(Demand Supply ratio-1))*SW+ (1-SW)*P0*

P0 is the price at the beginning, recent price is the current price, price sensitivity is 1 and the demand supply ratio is the change between demand and supply. SW is the price switch and its value is 1 and 0, when the switch is on the value will be 1 and 0 when the switch is off. If the SW value is 1 then it shows the dynamic pricing as a new price otherwise if the value is 0 then it shows the P0 (price at the beginning).

Demand Supply Ratio = Total Demand / Total Supply

Demand and supply ratio is the main function of this stock and flow diagram. It has the direct effect on the price. If the total demand is higher than the total supply then the price will go up like this if the total demand is equal or lower than the total supply then the price will go down.

Change in Recent Price = (Price-Recent price)/Time to Adjust Price

Change in recent price is the function of price and recent price divided by the time to adjust price. In other word the difference between the price and recent price and this difference divided by the time to adjust price.

Recent price= 8.30 NPR
Time to Adjust Price= 10 minutes

Recent price is the constant value taken from the NEA report, 2016. Like this time to adjust price is 10 minutes assumed.

Total Demand = Demand Inventory + demand

Total demand is the sum of demand inventory and demand.

Demand = Underlying Needs + Satisfaction of needs

Demand depends on the underlying needs of electricity and the satisfaction of needs. Demand has the positive relation between underlying needs and satisfaction of needs.

Underlying Demand = Graph (Graph from 0 to 24 hours (542, 700, 675, 660, 650, 690, 700, 690, 725, 700, 650, 600, 575, 560, 550, 550, 600, 800, 1444, 1300, 1100, 800, 700, 645, 630.)

Underlying demand is the historical data which is taken from the NEA (2016/17) report.

*Indicated Total Demand = (Demand Supply ratio * Underlying demand)*

Indicated total demand is the function of demand supply ratio and underlying demand. Underlying demand is the graphical function which is based on the historical data available on NEA (2016/17) report so indicated total demand mainly depends on the demand supply ratio. If the demand is high then the demand supply ration has positive relation with the indicated total demand vice versa.

Change Satisfaction of Needs = (Indicated Satisfaction of Needs - Satisfaction of needs) / Time to Adjust Satisfaction of Needs

Satisfaction of needs is equal to initial satisfaction of needs and indicated satisfaction of needs is function of price and price elasticity and time to adjust satisfaction of needs is equal to 10 minutes.

Indicated satisfaction of needs = (Price/P0)^(Price Elasticity of Demand)

To calculate the indicated satisfaction of needs, the price is divided by the price at the beginning and powered by the elasticity of demand.

Price Elasticity of Demand = -0.7 (assumed)

To calculate the price elasticity of demand, the following formula can be used.

$$Ped = P/Q * \Delta Q/ \Delta P$$

Where, Ped = price elasticity of demand.
P = Price
Q = Quantity of Demand.
ΔQ = Change in the Quantity of Demand.
ΔP = Change in the Price.

Price elasticity of demand is the price divided by the quantity of demand and multiple to the change in the quantity of demand divided by the change in the price.

In other words,

$$Ped = \%\Delta Qd / \%\Delta P$$

Where,
%ΔQd = Percentage Change in the quantity of Demand.
%ΔP = Percentage Change in the Price.

Ped is the percentage of change in the quantity of demand divided by the percentage of change in the price. How the changes in the price have effect on the quantities of demand is the elasticity of demand.

Supply Inventory = SW Inventory(IF Inventory<0.001 THEN 0 ELSE Relative Supply Inventory*Maximum Capacity to Change Inventory)*

Supply also another important part of this whole thesis. To determine the supply inventory the above equation is used in this model. Where,

SW Inventory = 1 and 0
And inventory is the function of maximum capacity to change and inventory and relative supply inventory.

Change in Relative Supply Inventory = (Potential Relative Supply Inventory - Relative Supply Inventory)/Time to Adjust Relative Demand Inventory

The difference between potential relative supply inventory and relative supply inventory and the divided by the time to adjust relative demand inventory is the change in relative supply inventory.
Time to Adjust Relative Demand Inventory is 10 minutes.

Potential Relative Supply Inventory = IF Inventory>0 THEN MIN(1, MAX(0, (Price-Price High)/2)) ELSE 0

Potential relative supply inventory determines by the inventory. If the inventory is higher than 0 then the potential relative supply inventory will be minimum 1 and maximum 0 or the difference between price low and price divided by 2 because potential relative supply inventory never be negative.

Total Supply = Supply Inventory +Solar Supply +Supply wind energy+ Imported from India + Purchase from IPP

Total supply is the sum of supply inventory, solar supply, supply wind energy, imported from India and the purchase from the internal power plant (IPPS)

Change in Wind Energy = (Indicated wind energy-wind energy)/Time to adjust wind energy

The change in wind energy is the difference between indicated wind energy and wind energy and divided by the time to adjust wind energy. Here the time to adjust wind energy is 30 minutes. Wind energy is represented by the stock.

3.1.1 Boundaries of the model

- The data uses in this thesis have been taken from the Nepal Electricity Authority (NEA, 2016/17) report.
- This model is only for monopoly market that means there is no other competitors to sell the electricity instead of NEA and the customers have no other options.
- The price of electricity is varying according to the purposes of uses like households, agriculture and business but here average price has been used as the price of the electricity for the all sectors.
- Economics theory has been used for describing the price elasticity of demand, demand and supply.

- It is assumed that the customers are more sensitive because when the price of electricity is low, they will use more electricity.
- It is also assumed that the supply is always less or equal with the demand of the electricity.
- The purchase of electricity from the India and IPPS remain stable during the whole period of simulation of this model.
- It is assumed that the price of electricity is changing in every minute depending on the demand.
- The number 0 and 1 use to off and on the switch.
- Adjustment time is sat according to need.

3.1.2 Setting for Simulation of the Model

- The Stella Architect software is used to run this model.
- The time step (DT) for this model is 1.
- The standard Euler method has been used.
- Model simulation duration time is 0.1 seconds.
- The time unit is set as minutes.

3.1.3 Equilibrium test of the model

Equilibrium tests also an important part of the modeling because it proves that all the flows and parameter are connected properly and able to show the behaviors. To run this model in equilibrium the following parameters need to set in order to get the result in equilibrium condition.

Initial inventory = 100
Demand Supply Inventory = 100
Price (P) = 9.30
Switch (SW) = 0
Blackout = 0

When we put the above value in the model then the model will show the following behavior.

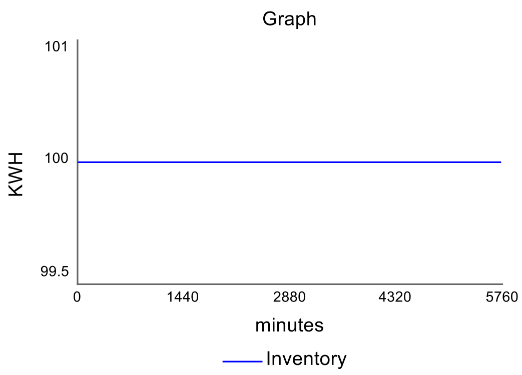

Figure 4:- Demand and Supply Inventory in Equilibrium.

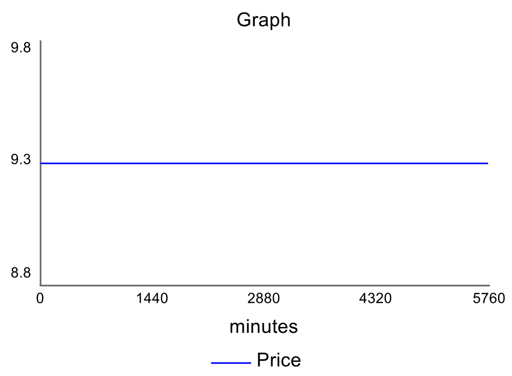

Figure 5:- Price at Equilibrium.

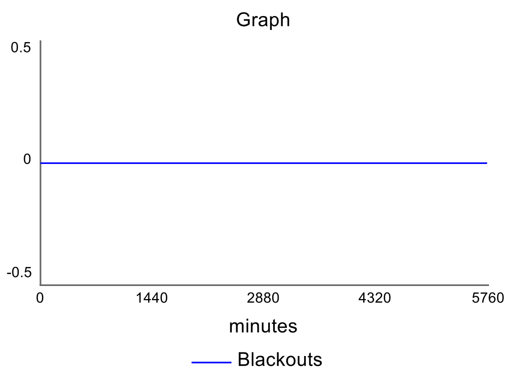

Figure 6:- No Blackouts in Equilibrium Condition.

In the above figure 4, 5 and 6 show the behavior of the model in the equilibrium condition. In the graph the demand and supply is equal at price 9.30 and there is no blackouts if demand and supply remain equal or no gap between them.

3.1.4 Simplified overview of the model

Below structure tries to simplify whole model and the causal loops relations among demand, supply and price.

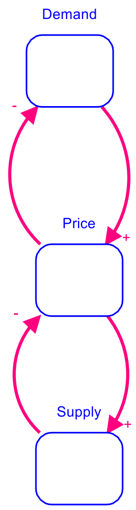

Figure 7:- Simplified overview of the model

Price is the central part of this whole thesis because it determines other part like demand and supply. In the above, the structure tries to show the relation between price, demand and supply. This structure shows that the balancing feedback loops between price and demand and price and supply. If the price is low then the demand will be high and that leads to decrease in the supply. Like this if the price is high then the demand will be lower and that leads to increase in the supply.

$$p\uparrow \rightarrow D\downarrow \rightarrow S\uparrow \rightarrow p\downarrow$$
$$p\downarrow \rightarrow D\uparrow \rightarrow S\downarrow \rightarrow p\uparrow$$

Where, p↑ denotes price high
P↓ is price low
D↓ is low demand
D↑ is demand high
S↓ is less supply
S↑ is high supply

3.1.5 Structure for Net Profit Inventory

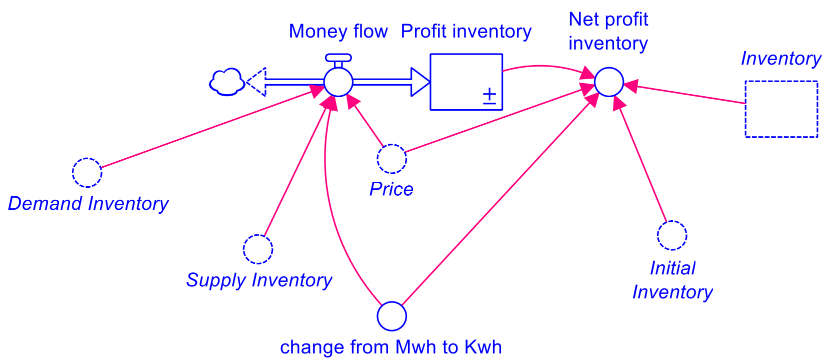

Figure 8:- Structure for Net Profit Inventory

The above figure shows the net profit structure of the model and their equations are as follows.

*Money Flow = ((Supply Inventory – Demand Inventory)*change from Mwh to Kwh) * Price*

Money flow is the difference between supply inventory and demand inventory and multiple of change from mwh to kwh and price.

Change from Mwh to Kwh = 1000

Change from mwh to kwh is the constant value used to convert mwh to kwh

Net profit Inventory = (Profit inventory + (Inventory- Initial Inventory) * Price) / change from Mwh to Kwh

Net profit inventory is the function of profit inventory added the different between inventory and initial inventory and multiple of price and whole divided by the change from Mwh to Kwh.

3.2 Causal Loop Diagram (CLD)

Causal loop diagram is also a system dynamics tool to simplify the problem which is presented in the stock and flow diagram. It helps us to understand the feedback mechanism and their effect in whole model.

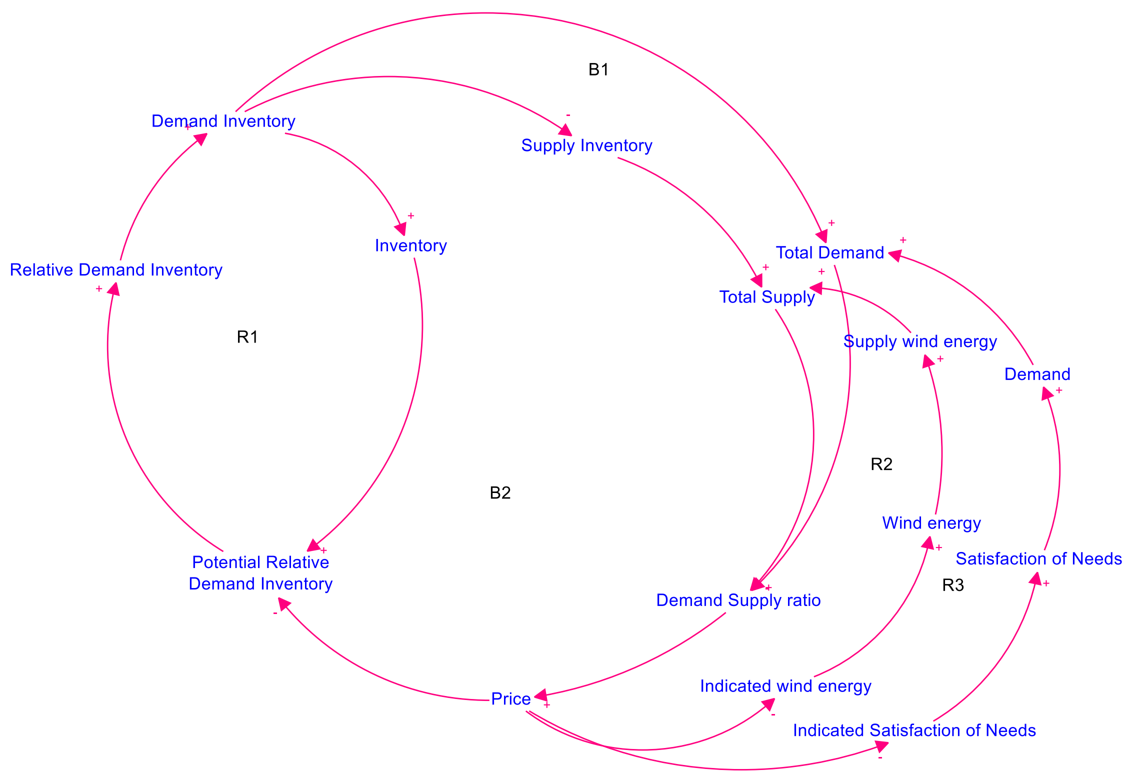

Figure 9:- Causal Loop Diagram (CLD)

Figure no 9 represents the casual loop diagram and this CLD has 4 reinforcing loops and two balancing (B1 and B2) loops. So in this casual loop diagram the balancing loops are the most important loop because they control all other reinforcing loops. In the figure balancing loops balance all other parameters. When demand increases the ration between demand and supply also increase and that leads to increase in the price also and the price has negative relation with the potential relative demand inventory. So B1loop is price and demand loop and it controls the demand in the short run, the price must be increased and that leads to decrease in the demand to balance the gap between demand and supply.

Another loop is B2 and it balances the supply of the electricity through demand supply ratio. There is a negative relation between demand inventory and supply inventory and the supply inventory has positive relation with total supply and that leads to negative relation with the demand supply ratio. In other words if the total supply is high then the demand supply ration will be low. So this balancing (B2) loop controls over the total supply, demand supply ratio, price and potential demand inventory to match the demand and supply.

Similarly the reinforcing loop (R1) shows the relationship between demand inventory, inventory, potential relative demand inventory and potential demand inventory. These all parameters have positive relation with each other. Like this another reinforcing loop (R2) shows the relationship between supply and price of the electricity. And the last reinforcing loop (R3) describes the relation among the price, satisfaction of needs and demand. If the price is increased then the satisfaction of need will decrease and the relation between satisfactions of needs with demand is positive so the demand also decreases.

3.3 Comparative studies of Satisfaction of Needs

Below table and figure no 12 describe the comparatives hourly satisfaction of needs by using dynamic pricing policy and without policy.

Hour	Without Policy	With Dynamic Pricing Policy	Difference
0	0.60	0.60	0
1	0.595	0.601	+0.06
2	0.591	0.602	+0.011
3	0.588	0.604	+0.017
4	0.584	0.605	+0.021
5	0.581	0.606	+0.025
6	0.578	0.607	+0.029
7	0.576	0.609	+0.033
8	0.574	0.610	+0.036
9	0.572	0.611	+0.039
10	0.570	0.613	+0.043
11	0.568	0.614	+0.046
12	0.567	0.616	+0.049
13	0.566	0.617	+0.051

14	0.565	0.619	+0.054
15	0.563	0.620	+0.057
16	0.563	0.621	+0.058
17	0.562	0.623	+0.061
18	0.561	0.624	+0.063
19	0.560	0.626	+0.066
20	0.560	0.627	+0.067
21	0.559	0.629	+0.070
22	0.559	0.630	+0.071
23	0.558	0.632	+0.074
24	0.558	0.633	+0.075

Table No 1:- Comparative satisfaction of needs.

Comparative hourly satisfaction of needs has been described in the above table no 1 and this table shows that the hourly satisfaction of needs is far better with smart market pricing policy than without policy.

4. BEHAVIOR TESTING

This chapter deals with the behavior testing. It also shows that how the behavior changes after and before the policy implementation. The behaviors of total demand, total supply, blackouts and satisfaction of needs have been presented in the below graph without the dynamic pricing and with the dynamic pricing and it is clearly shown the different between them in the graph.

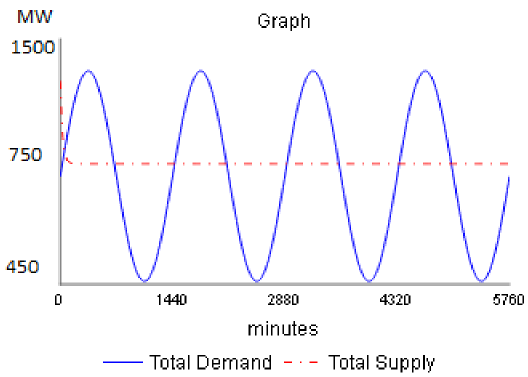

Figure 10:- Total demand and Total Supply before the Dynamic pricing.

Total demand and total supply are shown in the figure 10 before the implementation of the real time pricing policy. In the graph, total demand of electricity is up and down but the total supply of electricity is almost remaining constant. So we can clearly see the huge gap between demand and supply of electricity.

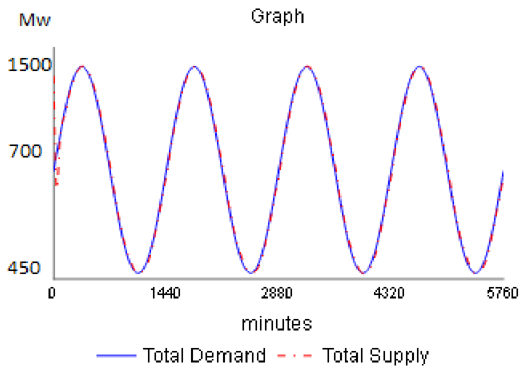

Figure 11:- Total demand and Total Supply after the Dynamic pricing.

Figure 11 shows the behavior of total demand and total supply after applying the dynamics pricing policy in the model. The blue line is the total demand and the red line represents the total supply. And there is no gap between demand and supply of the electricity. So the smart market pricing policy is the best fit policy to control the electricity demand and supply in the Nepalese electricity market. It controls the demand through the price. For instance, if the demand is higher than the supply then the price will go high and at the high price people use less electricity like this if the demand is low the price will be lower and people use more electricity.

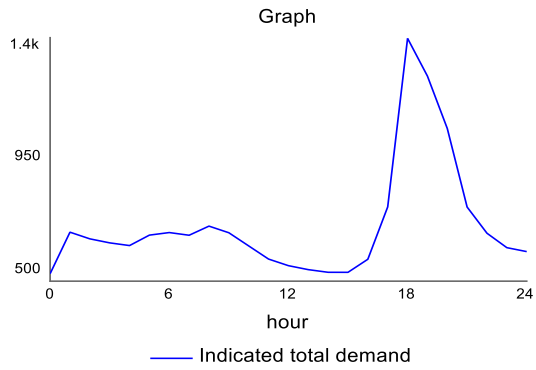

Figure 12:- Indicated Total Demand.

Figure no 12 shows that the indicated total demands in blue line over the 24 hours and this line able to replicate the reference mode of this study.

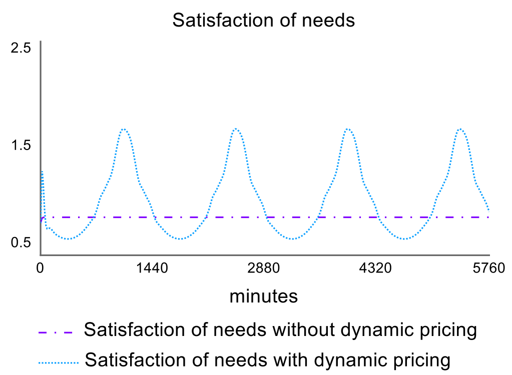

Figure 13:- Satisfaction of needs with and without dynamic pricing.

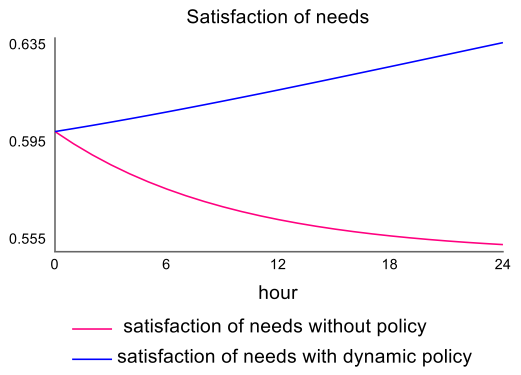

Figure 14:- Hourly Satisfaction of needs with and without dynamic pricing.

In the figure 13, the purple line shows the satisfaction of need without dynamic pricing and the green line shows the satisfaction of needs after using dynamic pricing. The satisfaction of needs is only 0.6 before the policy implementation and average 1.4 with the real time pricing policy. So the smart market pricing policy ensures the higher satisfaction of needs than the fixed price policy for the people.

Similarly in figure no 14 represents the hourly satisfaction of needs for 24 hours without policy and with policy. The blue line is with policy and the pink line is without policy. Both have 0.6 (assumed) satisfaction of needs at the beginning and the blue line (with policy) is increasing hour to hours to reach maximum of 0.633 at the end of 24 hours. Like this, the pink line (without policy) is decreasing from hour1 to hour 24 and remains 0.558 at the end. It shows some stable at the middle of hours.

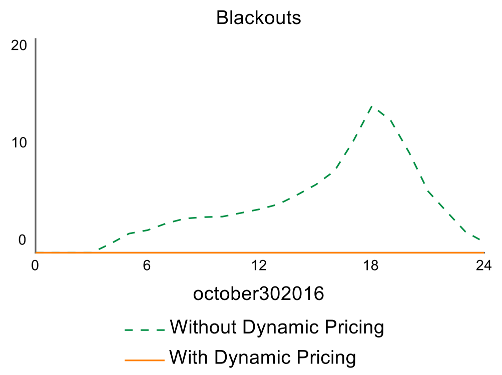

Figure 15:- Blackouts with and without dynamic pricing.

In the above figure no 15, it shows the blackout. The green line is showing the blackout without dynamic pricing that means with fixed price and the red line is also showing the zero blackouts in the country by using dynamic pricing policy.

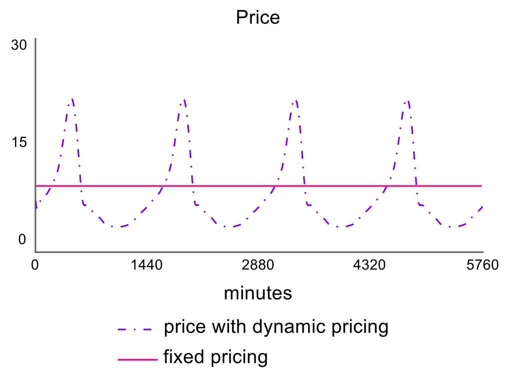

Figure 16:- Price with fixed and dynamic pricing policy.

In the above figure 16 shows that the difference between the price without policy and price after the policy. The red line is the price without policy which is NPR 9.30 and the pink one shows the price with dynamic pricing policy and this line shows the different price at different time interval. The highest price is NPR 21.70 and the lowest is NPR 3.56 and the price is changing in every two minutes. That's the way this policy fulfills the gap between demand and supply of electricity with the use of different prices at different time intervals.

5. POLICY TESTING

Testing of policy is the important aspect for the policy makers. Policy testing is the validation of whole things what I have done in the above chapters. Without testing the policy, it does not matter how good the policy is. After testing the policy than the result shows how much the policy is good or bad and should be implemented or not. To test the smart market policy, following issues should be discussed and analyzed, whether it can address those issues or not.

5.1 upgrading the existing system

This policy enables to upgrade the existing system and technology used in the production and distribution of electricity. People easily adopt the new technology so that is quite feasible to replace the old system by using advance one such as to replace the old metering system with new advanced metering interface (AMI) and automatic meter reading (AMR), both are currently available in the market as a latest technology to upgrade old one. AMI has the ability to communicate both ways while AMR communicates one way. The USA, Norway and France all countries are looking to use these latest technologies nationwide because it is beneficial not only users but also distributors and producers. The new technology also helps to decrease the system loss because Nepal has one of the highest system losses in the world almost 31 percent (NEA report, 2013) of the total production.

5.2 Economic point of view

This new smart market policy is possible to implement in the Nepalese electricity market from the economic point of view. By 1, January 2019, all the electricity users in Norway will get a smart meter (The Norwegian Water Resources and Energy Directorate, Jan 2017). By using this advanced metering system (AMS), consumers able to receive advanced information about their electricity consumption and it gives a correct and accurate meter reading and better opportunities to engage in demand response. The lowest cost per meter is NOK 1700.00 which is equivalent to NPR 21454.00 (Exchange Rate 12.62, Central Bank of Nepal), which is not expensive and affordable in the Nepalese electricity market.

Currently, Nepalese people are using alternatives means of electricity during the period of load shedding, which is neither cheap nor efficient such as back up batteries, inverters and diesel or patrol generators. These alternatives cause peak load to further escalate and these equipments are high cost alternatives than hydro electricity. So from the view point of cost this policy feasible in Nepal because it will give information about the peak hours and off hours cost and customers have choices whether to use or stop the usage of electricity.

5.3 Changes in Social Thinking

It is not easy to change the thinking and thought of society at once to implement new policy, it takes time so it is better to implement the changes in phase wise plan and that will be quite easy to adopt new policy in the society. Sooner or later the new policy will definitely accepted by the society after realizing the benefit of new policy because it is always in the favor of society and the nation.

The European country, Norway has been using smart metering system from 2015 and planned to finish in 2019 (The Norwegian Water Resources and Energy Directorate, Jan 2017). At the beginning it started to allocate smart metering system at limited society and after successful completion it attracted other society also. So now they have planned to implement smart metering system to the whole nation till 2019. So from the view point of society, the new policy will be accepted in Nepal but it takes time.

5.4 Effective Leadership

To implement new policy, effective, realiable and responsible leadership should be needed otherwise it is not possible to implement new policy. In the context of Nepal to impose new policy, the Government of Nepal (GoN) and Nepal Electricity Authority (NEA) have to take the role of leadership. NEA is the sole electricity distributor in the country and it has generated more than 70 percent of electricity in Nepal. NEA also collects tariff from electricity users on monthly basis in Nepal so it will be better for policy maker the NEA should lead from the front to implement the new policy in Nepal.

In Norway the DSOs (Distribution System Operators) has taken leadership on the behalf of public owned organization to distribute smart metering system in the country. There are more than 160 small distribution system operators (DSOs) in Norway, most of them publicly owned.

The important issues have been described in the above about the testing of new policy in Nepalese electricity market. After analyzing these issues, it is possible to implement the new policy which is called real time pricing policy. So the purposed policy is relevant especially in the electricity market to eradicate load shedding from the country in the short run.

6. CONCLUSIONS & SUMMARY

6.1 Conclusions

This chapter deals with the summary and conclusions of the whole study. The main theme of this study is the blackout also known as load shedding in Nepal. This is a big problem and this problem is facing from the last one decade by the Nepalese people. Although, Nepal has the huge potential of electricity with 8300 MW of them 4300 MW is technically and economically feasible but still half of the Nepalese people live in the blackouts. The main reason behind the blackout is that the demand of electricity higher than the supply of electricity so overall the production of electricity is unable to match the demand. This thesis mainly concern to solve the blackout in short term and able to fulfill the gap between demand and supply of electricity through the smart market pricing policy. This study shows that the fixed price regulated electricity market is the main cause of the load shedding in Nepal because in the fixed price market, people have no incentives to postpone their habit so that the demand will be always higher than the supply and that creates huge gap between them and to fulfill the gap, the NEA manages electricity through the power cut because they do not have other options.

This thesis is mainly focused to solve the load shedding problem from the country by using the new policy which is called smart market pricing. These policies is actually useful for the short term and at the end in the long run to balance the gap between the demand and supply, the Government of Nepal (GoN) and Nepal Electricity Authority (NEA) have to bring new policy to invest money on hydro power to generate more electricity. The real time pricing policy mainly focuses on the prices so the varying prices can bring equilibrium between demand and supply. This policy divides the uses of electricity like peak hours users, normal hour users and off hour's users. Peak hour's electricity users pay peak price and normal hours and off hour's user have to pay less and normal price respectively.

This new smart market pricing policy able to bring equilibrium between demand and supply of electricity and that leads to increment in the satisfaction of needs of the customers. So this policy is better option for the short term to stop load shedding from the country. Customers have their own choices, how and when to use the electricity according to the needs. They can also divide their needs like which is most important and which is less. The power is always accessible to them. So there is no doubt, it increases the customer's satisfaction of needs. So it is the best fit policy in the electricity market of Nepal.

Electricity is the backbone of the country so this policy in the short run can bring new era in long run in the electricity market of Nepal because this policy definitely increases the profit of NEA by selling the electricity in high price during peak hour and that profit can be used for further electricity generation. It can also attract private sectors to invest money on hydro electricity power. So this policy can help to generate more electricity in the long run. Furthermore, the government also gives focus on wind and solar energy as a alternative sources of electricity.

Nepal has more than 6000 rivers and all the hydro powers except Khulakhani Hydro Power (KHP), are run of rive (RoR) type. Only Khulekhani Hydro Power plant has the storage capacity. During the dry season, the water levels in the rivers are very low and that has the direct effect on the generation of electricity. System loss also has huge impact on the distribution of electricity in Nepal to increase load shedding. Nepal has one of the highest system losses in the world almost 31 percent (NEA report, 2013) of the total production.

To eradicate load shedding form the country, the Government of Nepal (GoN) also needs to make investment friendly policy to attract foreign investors to invest on hydro electricity power. Nepal also has huge potential of exporting electricity to its big and rising and developing neighbor countries, India and China because it shares borders with them. So without the long sighted policy and vision, it is not possible to eradicate blackouts from the Nepal.

6.2 SUMMAREY

The summary of the whole thesis are as follows.

- The fixed price on electricity is the main reason behind the load shedding in Nepal because it is not able to fulfill the gap between demand and supply of the electricity
- The generation of the electricity is very lower than the demand and the demand is increasing faster than the production.
- The short sighted and defective policy and vision of Government of Nepal (GoN) and Nepal Electricity Authority (NEA) also another reason of load shedding in Nepal.

- Nepal has the huge potential of electricity with 83000 MW of them economically and technically 43000 MW is feasible but still more than fifty percent people do not have electricity access.
- Smart market policy is the best fit policy in the electricity market of Nepal because it helps to match the demand and supply to eradicate blackouts from the country.
- The dynamic pricing policy has the positive relation with the satisfaction of needs of the customer. It has better satisfaction of needs than the fixed pricing policy.
- This policy would encourage customers to adjust energy consumption to take the benefit of lower price energy in the off hours and to limit usage in peak hours; as a result customers should take advantage from a more efficient electric system.
- This policy can also attract the national and international investors to invest on hydro power electricity.
- Smart market pricing policy gives time to GoN and NEA to make new policy for the future electricity market.
- The main important thing is that this dynamic pricing policy able to fill the gap between demand and supply of the electricity in the short run.

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APPENDIXN

Equations and units used in the model.

Name	Unit	Definitions	Variable Type	Stock/ Flow/ Converter
Demand Inventory	MW/ Minute	SW Inventory * Maximum Capacity to Change Inventory * Relative Demand Inventory	Auxiliary	Flow
Inventory	Mwh	Initial Inventory	Constant	Stock
Supply Inventory	MW/ minute	SW Inventory * (IF Inventory<0.001 THEN 0 ELSE Relative Supply Inventory * Maximum Capacity to Change Inventory)	Auxiliary	Flow
SW Inventory	Dmnl	1 or 0	Constant	Converter
Maximum Capacity to Change Inventory	Kwh/ minute	6000Kwh	constant	Converter
Relative Demand Inventory	Dnml	0	Constant	Stock
Change in Relative Demand Inventory	Per Minute	(Potential Relative Demand Inventory – Relative Demand Inventory) / Time to Adjust Relative Demand Inventory	Auxiliary	Flow
Potential Relative Demand Inventory	Dmnl	IF Inventory<Maximum Inventory THEN MIN(1, MAX(0, (Price Low - Price)/2)) ELSE 0	Auxiliary	Converter
Maximum Inventory	Kwh	6000Kwh	Constant	Converter
Price Low	NPR/ kwh	Price High – Price Difference	Auxiliary	Converter
Price Difference	NPR/ kwh	1.00 NPR	Constant	Converter

Price High	NPR/ kwh	9.30 NPR	Constant	Converter
Relative Supply Inventory	Dmnl	0	Constant	Stock
Change in Relative Supply Inventory	Per minute	(Potential Relative Supply Inventory – Relative Supply Inventory) / Time to Adjust Relative Demand Inventory	Auxiliary	Flow
Time to Adjust Relative Demand Inventory	Minutes	10 minutes	Auxiliary	Converter
Potential Relative Supply Inventory	Dmnl	IF Inventory>0 THEN MIN(1, MAX(0, (Price – Price High)/2)) ELSE 0	Auxiliary	Converter
Price	NPR/ kwh	Recent price * (1+Price Sensitivity * (Demand Supply ratio-1)) * SW+(1-SW) * P0	Auxiliary	Converter
Recent Price	NPR/ kwh	8.30	Auxiliary	Stock
Change in Recent Price	NPR / / kwh /Minute	(Price – Recent price) / Time to Adjust Price	Auxiliary	Flow
Time to Adjust Price	Minute	10	Constant	Converter
P0	NPR/ kwh	9.30	Constant	Converter
Price Sensitivity	Dmnl	1 And 0	Auxiliary	Converter

Demand Supply Ratio	Dmnl	Total Demand / Total Supply	Auxiliary	Conve rter
Total Demand	Mwh /minut e	Demand Inventory + demand	Auxiliary	conve rter
Total Supply	Mwh/ minut e	Supply Inventory + Solar supply + Supply wind energy + Imported from India + Purchase from IPP	Auxiliary	Conve rter
Blackouts	Mwh	MAX(0, Total Demand – Total Supply)	Auxiliary	Conve rter
Solar Supply	Mwh/ minut e	0.8	Auxiliary	Conve rter
Imported from India	Mwh/ minut e	240	Constant	Conve rter
Purchase from Internal Power Plant	Mw/ minut e	260	Constant	Conve rter
Supply Wind Energy	Mwh/ minut e	Capacity of wind energy * wind energy	Auxiliary	Conve rter
Capacity of wind Energy	Mwh/ minut e	85	Auxiliary	Conve rter
Wind Energy	Dmnl	Initial wind energy	Auxiliary	Stock
Change in Wind Energy	Per minut e	(Indicated wind energy – wind energy) / Time to adjust wind energy	Auxiliary	Flow
Time to Adjust Wind Energy	minut e	30	Constant	Conve rter

Initial Satisfaction of Needs	Dmnl	0.8	Constant	Converter
Demand	Mwh/minute	1448	Auxiliary	Converter
Underlying Needs	Mwh/minute	60+30*SIN(2*PI*TIME/(60*24))	Auxiliary	Converter
Satisfaction of Needs	Dmnl	Initial satisfaction of needs	Auxiliary	Stock
Change in Satisfaction of Needs	Per minute	(Indicated Satisfaction of Needs - Satisfaction of needs) / Time to Adjust Satisfaction of Needs	Auxiliary	Flow
Time to Adjust Satisfaction of Needs	Minutes	10	Constant	Converter
Indicated Satisfaction of Needs	Dmnl	(Price/8.30)^(Price Elasticity of Demand)	Auxiliary	Converter
Price Elasticity of Demand	Dmnl	-0.7 (Assumed)	Auxiliary	Converter
Initial Wind Energy	Dmnl	0.8	Constant	Converter
Indicated Total Demand	Mwh	(Demand Supply ratio * Underlying demand)	Auxiliary	Converter
Underlying Demand	Mwh	Graph from 0 to 24 (542, 700, 675, 660, 650, 690, 700, 690, 725, 700, 650, 600, 575, 560, 550, 550, 600, 800, 1444, 1300, 1100, 800, 700, 645, 630)	Auxiliary	Converter
Price coefficient	Npr/Kwh	1	Constant	Converter

Money flow	NPR/ Minute	((Supply Inventory – Demand Inventory) * change from Mwh to Kwh) * Price	Auxiliary	Flow
Profit Inventory	NPR	0	Auxiliary	Stock
Change from Mwh to Kwh	Kwh/ Mwh	1000	constant	Converter
Net Profit Inventory	NPR	(Profit inventory + (Inventory – Initial Inventory) * Price) / change from Mwh to Kwh	Auxiliary	Converter

Note: - The data used in the above are taken from the NEA annual report 2016/17.