OPEN ACCESS

International Journal Of Modern Engineering Research (IJMER)

Framework Development to Analyze the Distribution System for Upper Karnali Hydropower Project Affected Area

Ashish Shrestha[1,*], Bibhu Bikram Shah[2], Bidur Raj Gautam[2], Shailendra Kumar Jha[1]

[2]School of Engineering, Kathmandu University, Nepal

[2]Office of The Investment Board Nepal, Government Of Nepal

*Corresponding Author: sthashish2010@gmail.com (Ashish Shrestha)

ABSTRACT: *Upper Karnali Hydropower Project is a 900 MW run of river hydro project in Nepal, from where the generated power will be transmitted to Indian grid via a dedicated transmission line, and hence local consumers will not be fed through this plant. As per the concession agreement executed between the Government of Nepal and the developers, a 2 MW hydro plant shall be developed at the toe of the dam by using the environmental release discharge. A previous study conducted by the authors, identified the optimal electric network, taking into consideration different factors such as demography, topography, socio-economic and technical feasibility. In this study, however, the authors analyze the performance of the system by carrying out a techno-economic study using computational grid network design analysis. A framework for Load Flow Analysis is developed and used to analyze the developed network. For verification, the results obtained are compared with those from standard 33 bus radial distribution feeder system and Forward/Backward based Sweep algorithm creating paired sample T-test. No significant difference between the results for a 95% confidence of interval is observed. After observing the results, it is concluded that the developed framework, as well as the grid network, are technical, computationally and economically efficient.*

Keywords: *Load Flow Analysis; Newton-Raphson; Primary Distribution System*

I. INTRODUCTION

A distribution system is the line connecting step down transformer and a load center. It is used to distribute the power from load transformer to the consumers. The primary distribution system is the part which operates at a higher voltage level than the utilization voltage and handles higher electrical loads [1]. In the case of Nepal, the secondary distribution voltage is 230/400 V. The primary distribution system voltage is 3.3kV, 6.6kV, 11kV, 22kV or 33kV. Variation in utilization voltage occurs due to the voltage drop in conductors and is dependent of the network design. As per the rules and regulations of Nepal Electricity Authority (NEA), the voltage and frequency fluctuation shall not be more than 5% and 2.5% respectively [2]. However in rural electrification, the voltage drop is found to be very high resulting in variation of utilization voltage level from one user to another [3]. Efficient and reliable technology must be applied in planning and design of the distribution system, so that a suitable and efficient result can be obtained.

Planning, operation and control of power systems are directly associated with the load characteristics and voltage magnitude. The voltage stability is dependent on load behavior with the variation in voltage and frequency [4]. Load Flow Analysis (LFA) is an important tool used in planning, operation, and design of electrical systems to determine the best operation state of a system [5]. Some of the researches explained the role of SCADA system in automation of electrical system by distributing and parallelizing features [6, 7]. There are numerous techniques of LFA, such as; Gauss-Seidel, Newton-Raphson, Fast Decoupled, Forward/ Backward Sweep based algorithm etc. [4, 5, 8-12]. It is found that, the N- R method is the most usable due to the least number of iterations and fast convergence [5]. However, the conventional N- R and Gauss-Seidel methods may not be good for the analysis of distribution systems, due to some special features such as suitability only to radial structures, high R/X ratio and suitability for stable loads [11]. Similarly, the fast decoupled power flow method is the improved method of N-R and popular for its calculation simplifications, fast convergence and reliability [5]. On the other hand, forward/backward sweep based algorithm does not use Jacobian matrix and does not converge accurately in heavy load conditions, exhibiting a complex and time consuming result [13].

In this study, an N-R based framework is developed for LFA of distribution system that electrify the Upper Karnali Hydropower Project (UKHPP) affected area. The objective is to identify the stable grid network with technical as well as economic feasibility. The performance of the network is analyzed taking into account related parameters to identify the optimal design and solution.

II. NEWTON RAPHSON METHOD

N-R Method is an iterative method which approximates a set of simultaneous non-linear algebraic equations to solve an expression. It is based on successive approximations and used for load flow analysis in power system studies because of its powerful convergence and reliability [14]. The algorithm can only execute with real equations and variables. Therefore, equations are present in complex form (i.e. real and imaginary components). It can also be presented in a polar form. The expression of active and reactive power at n bus and the complex power at bus i is given below [15],

$$P_i - jQ_i = V_i^* I_i = V_i^* \sum_{k=1}^{n} Yik\ Vk = \sum_{k=1}^{n} |Yik\ Vi\ Vk|\ e^{j(\theta ik + \delta k - \delta i)}$$
$$= \sum_{k=1}^{n} |Yik\ Vi\ Vk| Cos(\theta ik + \delta k - \delta i) + j \sum_{k=1}^{n} |Yik\ Vi\ Vk| Sin(\theta ik + \delta k - \delta i) \text{ --------- (1)}$$

Where P_i and Q_i stands for active and reactive power at bus i. V_i and V_k is the voltage (pu) of i^{th} bus and k^{th} bus respectively. In the above expression, the i^{th} bus is considered as the sending end bus and k^{th} bus is the receiving end bus. Similarly, Y_{ik} is the mutual admittance between busses i and k. θ_{ik}, δ_k, δ_i stands for the phase angle of the line admittance and bus voltages respectively.

Then, the active and reactive power is given by,

$$Pi = \sum_{k=1}^{n} |Yik\ Vi\ Vk| Cos(\theta ik + \delta k - \delta i) \text{ and}$$
$$Qi = \sum_{k=1}^{n} |Yik\ Vi\ Vk| Sin(\theta ik + \delta k - \delta i) \text{ -------------------------- (2)}$$

Let the active and reactive power generated at bus i be P_{Gi} and Q_{Gi}, and the active and reactive load be P_{Li} and Q_{Li} respectively. Then the net injected power in bus i is,

$$P_{i,\,inj} = P_{Gi} - P_{Li} \text{ and}$$
$$Q_{i,inj} = P_{Gi} - Q_{Li} \text{ ------------------------------- (3)}$$

Let the injected power calculated by the load flow program be $P_{i,\,cal}$ and $Q_{i,\,cal}$. Then the mismatch between the actual injected and the calculated value is,

$$\Delta P_i = P_{Gi} - P_{Li} - P_{i,cal} \text{ and}$$
$$\Delta Q_i = Q_{Gi} - Q_{Li} - Q_{i,cal} \text{ --- (4)}$$

Now, let us consider that an N-bus system having total n_p number of P-Q buses, where a generator bus with number n_g is presented. Then,

$$N = n_p + n_g + 1 \text{ ------------------------ (5)}$$

Where 1 is for the slack bus. Here the variables are V and θ for each PQ bus and θ for each PV bus. For PV and slack bus, the magnitude of voltage is not variable, but fixed at their specified values. Similarly the value of θ is fixed for slack bus. The mismatch equations of (4) is to be used because of the same approach of solving a non-linear equations by using numerical methods.

Now, the final expression for the load flow analysis is given below [16],

$$F(X^{(i)}) = J^{(i)} \Delta X^{(i)} \text{ --------------------- (6)}$$

Where,

$$F(X^{(i)}) = \begin{bmatrix} f1\{x1(i),\ x2(i), \dots \dots \dots ..xn(i)\} \\ f2\{x1(i),\ x2(i), \dots \dots \dots ...xn(i)\} \\ \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \\ fn\{xi(i),\ x2(i), \dots \dots \dots ...xn(i)\} \end{bmatrix}$$

$$J^{(i)} = \begin{bmatrix} \frac{\partial f1}{\partial x1}\Big|i & \frac{\partial f1}{\partial x2}\Big|i, \dots \dots \dots \dots \dots . & \frac{\partial f1}{\partial xn}\Big|i \\ \frac{\partial f2}{\partial x1}\Big|i & \frac{\partial f2}{\partial x2}\Big|i, \dots \dots \dots \dots \dots . & \frac{\partial f2}{\partial xn}\Big|i \\ \dots \dots \dots & \dots \dots \dots \dots \dots \dots & \dots \\ \frac{\partial fn}{\partial x1}\Big|i & \frac{\partial fn}{\partial x2}\Big|i, \dots \dots \dots \dots \dots . & \frac{\partial fn}{\partial xn}\Big|i \end{bmatrix} \text{ and}$$

$$\Delta X^{(i)} = \begin{bmatrix} \Delta x1(i) \\ \Delta x2(i) \\ \dots \dots . \\ \Delta x3(i) \end{bmatrix}$$

At each iteration, a square matrix is formed called Jacobian matrix [J(i)], generally used for solution correction. It is highly used for big network calculations. The elements of the Jacobian matrix are the partial derivatives evaluated at $X^{(i)}$.

Using expression (6), numbers of nonlinear equations can be solved to get unknown parameters in load flow of the electrical system. Further, the power loss in the branch connecting busses i and k is given below [12],

$$P_{loss}(i, k) = R_i \frac{(Pi)^{\wedge}2+(Qi)^{\wedge}2}{(Vk)^{\wedge}2} \text{ and}$$
$$Q_{loss}(i, k) = X_i \frac{(Pi)^{\wedge}2+(Qi)^{\wedge}2}{(Vk)^{\wedge}2} \quad \text{------------------- (7)}$$

Where $P_{loss}(i, k)$ and $Q_{loss}(i, k)$ are the active power loss and reactive power loss in the line section connecting buses i and k. The total power losses of the system, P_T can be calculated by adding the losses of all of the sections, which is given as

$$P_T = \sum_{k=1}^{n} Pl(i, k) \text{ and}$$
$$Q_T = \sum_{k=1}^{n} Ql(i, k) \quad \text{-------------------------- (8)}$$

Where P_T and Q_T are the total active power loss and total reactive power loss in the system.

III. UPPER KARNALI HYDROPOWER PROJECT (UKHPP)

UKHPP is one of the ambitious ROR type projects for Nepal located in the western region with an installed capacity of 900 MW. Figure 1 shows the administrative map of Nepal, where the location of UKHPP is highlighted. As per its design, the project foot print covers a large area, estimated to be 282.56 hectares (46.8 Hectare private and 235.76 Hectare Government land) affecting twelve Village Development Committee(VDCs) of Surkhet, Dailekh and Achham districts. In 2011, there were 10,502 households and among them 56 households are expected to be displaced by the project. Among the total households only 88 were connected to local electrical utility and the rest relied on alternative sources such as kerosene, bio gas, solar etc. for lighting loads [17, 18]. As per Hydropower Development Policy, 2001 and as part of benefit sharing, hydropower projects are encouraged to provide access to electricity to the affected areas [19]. The concession agreement executed between the developer of UKHPP and the Government of Nepal puts the onus on the government for the distribution of the 2 MW power plant electricity.

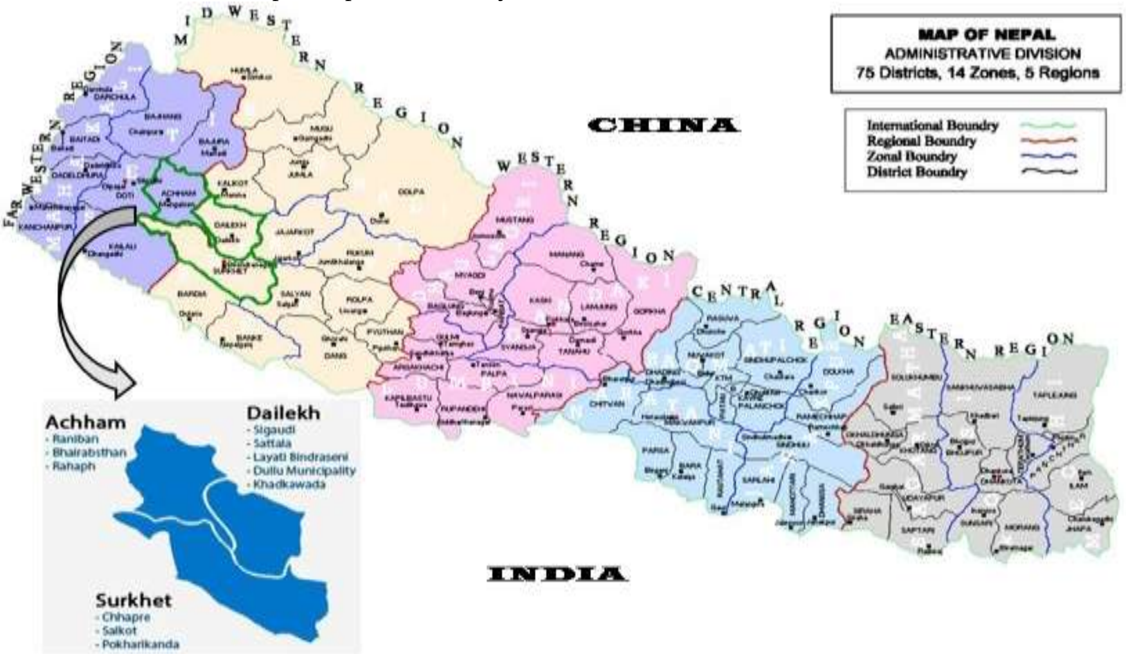

Figure 1: Administrative Map of Nepal

A study conducted previously identified the optimized electrical grid network for the project affected area of UKHPP, the details of which are explained in chapter 4.2.1. The study was done to identify possible load centers and connect them through an optimized network design based on demography, topography, technical feasibility and socio-economic factors. The design was based on the survey using GIS, Topographical maps, and satellite views of Google map. The architecture of the optimized network is presented in figure 2 [20].

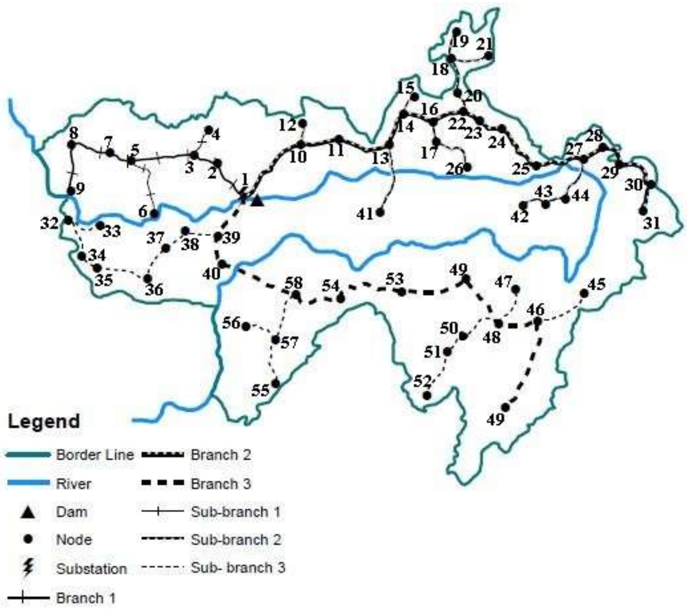

Figure 2: Optimized Network and the load Centers

Figure 2 shows the optimized network for rural electrification of UKHPP affected area. There are 57 load centers with one substation node. The electrical power that is produced by the 2 MW project will be distributed to the whole area through the substation located at node 1. To simplify the network and its analysis, the whole system is divided into 3 branches with their sub branches as shown in figure 2. For each branch, a linear system is drawn between the substation of the particular branch and the furthest load centers, so that analysis can be done easily. The distances between distinct load centers and total distances for all of the branches are given in table l.

IV. METHODOLOGY

To achieve the defined objective, a framework was prepared to select, review, develop, and operate the model for static load flow analysis. Computational algorithm was developed using the framework in MATLAB. The required data and components are given in chapter 4.2. After completion of the computational analysis for static load flow analysis, the characteristics were analyzed and presented. The results were verified by comparing them with those of standard 33-bus radial feeder system and the Forward/ Backward (f/b) Sweep based algorithm sweep based algorithm. For the f/b sweep algorithm based load flow analysis, Distribution Systems Power Flow Analysis Package using MATLAB GUI (DSPFAP) was used [11]. The comparison was done using statistical analysis to verify the framework's performance, and presented in table 4 below. Statistical parameters such as mean, standard deviation and standard error mean etc. were calculated using paired sample T-test.

A. Algorithm

In order to develop the framework and analyze the case, the algorithm used is described below:
Step 1: Start the iteration
Step 2: Read the line data (Resistance per km, Reactance per km, Susceptance per km and Distance), and bus data (Voltage, angle, active power and reactive power).
Step 3: Formulate the Jacobian Matrix using the real and reactive power equations.
Step 4: Calculate the real and reactive power flow of all branches using the nonlinear equations and conventional NR method.
Step 5: Update the node voltage and angle
Step 6: Check the convergence of the iteration, print the result and stop.

B. Data Required and Assumption

1) Selection of Load Center and Grid Network

The load centers for rural electrification of the affected area were identified based on different factors such as demography, topography, socio-economic and technical feasibility. Firstly, the area was divided into a number of sub divisions based on the affecting factors and analyzed with respect to different population densities and accessibility. The analysis was conducted with the help of data provided by the Governmental records, GIS, Topographical map and satellite view of Google maps. Based on mathematical calculations and using Monte-Carlo Simulation the sub divided area load centers were identified. Using Kruskal's algorithm, the network was optimized while considering the technical, physical, environmental, economic and social factors [20].

2) Load Demand

Nepal is a mountainous country with a theoretical potential of 83,000 MW, technical potential of 45,000 MW, and 42,000 MW of economically feasible hydroelectricity potential [21]. But, only 76 % of Nepalese population have access to electricity with energy consumption of 128 kWh per capita per year [22, 23]. Among them, 12% of Nepalese people use renewables such as solar, wind and micro hydro power plant for electricity [24]. Those connected to the national grid still face power cuts of up to 12 hours per day during winter seasons and 2-4 hours during rainy seasons [25].

Load patterns are distinct and vary from one geographic location to another. Territory to territory difference in altitude has its own effects and differs from one political state to another. This variability of electricity load patterns and its effect in demand makes it difficult to generalize their potential electrical demand. The work becomes more difficult especially in the un-electrified area. However, a tentative demand is required for selecting conductors, transformers and other parameters within a reasonable acceptable level so that no problems occur in the future. So, the households of the affected area are assumed to be under tire 3 category (i.e. minimum 200 W load demand, minimum 1 kWh consumption per day, minimum 8 hours availability duration per day and minimum 3 hours per evening).

3) Voltage level Selection

The empirical formula for Economic Voltage Level is given by equation,

$$V = 5.5\left(0.6\,L + \frac{3P}{100}\right)^{0.5} \quad \text{--------------------------------(8)}$$

Where V is the economic voltage level in kV, L is the total length of the line in km and P is the power to be transmitted in Power in kVA. The probable voltage level of grid line depends upon the length of the line and power to be transmitted. In the case study, there are 3 branches as shown in figure1. Total length and the longer distance for each branch is given in table 1 below. The peak demand for each branch is also given. The peak load for each branches are multiplication of the households that would be supplied by respective branches, and peak demand assumed per household (i.e. 200 W). The most economic voltage level for all of the branches are calculated by using equation (8), and tabulated in the same table below. Since, different values of economic voltage level are obtained, an optimized value (i.e. 33 kV) is considered by trial and error method. This is done to minimize the complexity of the analysis.

Table 1: Economic Voltage Selection

Network	**Distance Length (km)**	**Total Grid Length (km)**	**Peak Demand (kW)**	**Economic Voltage Level (kV)**	
				Calculated Value	**Remark**
Branch 1	14.77	20.48	465.4	26.27	33 kV Selected
Branch 2	33.01	56.89	1190	40.97	
Branch 3	33.81	67.22	889.6	37.69	

4) Conductor Selection

The transmission and distribution of a power system must also be considered for efficient and cost effective electrification. In the transmission of electrical power, the resistance and reactance of the conductor also plays an important role. Resistance is responsible for the power loss in the system and voltage regulation affects the quality of the service. So, the conductor should be selected with possible low resistance and low voltage regulation. Therefore the system must be optimized taking into consideration the aforementioned factors. Table 2 provides some conductor's ratings, which are highly used in distribution systems.

Table 2: Conductors with their Parameters [26]

Code Name	Resistance at 20^0C	Tensile Strength	Overall Diameter	Current Rating (A)		Inductive Reactance at 30mm spacing
	Ohm/km	**N/mm^2**	**mm**	**In still Air**	**With Wind**	**Ohm/km**
Mole	2.718	407	4.5	40	70	0.352
Squirrel	1.374	771	6.33	76	120	0.325
Gopher	1.098	952	7.09	85	130	0.318
Weasel	0.9116	1136	7.77	95	150	0.314
Ferret	0.6795	1503	9	115	175	0.308
Rabbit	0.5449	1860	10.05	135	200	0.305

In an electrical system there are some rules and regulations of local utility for maintaining the standard and quality of all electrical parameters. In case of Nepal, the distribution system should be maintained with fixed accuracy (2.5% of frequency and 5% of voltage) [2]. For a proper system, the designed voltage regulation should be less than 5%. Equation (9) and (10) are normally used to calculate the voltage regulation of a distribution line [26].

$$VR\ (\%) = \frac{1.06 \cdot P \cdot L \cdot PF}{LDF \cdot RC \cdot DF} \quad \text{--------------------------------------} \quad (9)$$

$$\text{And } RC = \frac{kV \cdot kV \cdot 10}{(R \cdot Cos\phi + X \cdot Sin\phi)} \quad \text{------------------------------------} \quad (10)$$

Where, P is the total power in kVA and L is the length of the line in km for respective branches. LDF be the Load Distribution Factor. LDF is based on load on the bus and is the percentage of load on a bus to total load within a set of load buses. Generally, maps are used to allocate the aggregate loads and determine the value of LDF. In the case, the distribution load is considered to be uniformly distributed, for which the value of LDF is 2.

Similarly, RC is the Regulation Constant in pu and formulates as given in equation (10). It is a constant in kW-km on the basis of 1% voltage drop considered to select the voltage regulation within permissible limits. Finally, DF be the diversity factor in pu. Generally, it is used by the electric utilities in design for distribution transformer and conductor sizing and load prediction. Greater the value of DF, lower is the total installation cost of the system. Mathematically, DF is the ratio of installed load and running, and the value is usually more than one. But, it is not same for all cases such as in distribution network, switchboards circuit function and apartment blocks. The value of DF for more than 50 blocks is 0.4 as given by IEC standard. In the case study, there are 58 load buses and each bus is considered as a block [27, 28].

Using the equations, the current rating and maximum voltage regulation for each of the branches were calculated, and are presented in table 3 below. As shown in the data, mole conductor was found to be best for branch 1, weasel conductor for branch 2 and squirrel conductor for branch 3. The conductors were selected, so that the voltage regulation of the branch (network) is less than 5%.

Table 3: Conductor Selection for Different Network

Branch	Peak Demand (kW)	Current Rating (A)	Voltage Regulation (%)				Conductor Selection
			Mole	**Squirrel**	**Gopher**	**Weasel**	
Branch 1	465.4	9.05	1.99	1.09	0.89	0.77	Mole
Branch 2	1190	23.13	11.4	6.26	5.11	4.38	Weasel
Branch 3	889.6	17.29	8.09	4.45	3.63	3.12	Squirrel

V. RESULT

The proposed framework and algorithms were implemented for this case study having 57 load centers and a source center (slack bus) to analyze the load flow. Considering the tire 3 category, the peak demand required to electrify the affected area based on explained assumptions was found to be 2602.1 kW of active power and 2307.4 of kVAR reactive power. These data showed that, the generated power will be insufficient to electrify the affected area of UKHPP. The losses for this case were found to be only 2.04%. Using the same conductors and parameters, the algorithm was then run for 400 W peak demand per household. In this case, the powers calculated were 5314.9 kW active and 4638.56 kVAR reactive. Losses amounted to 219.9 kW of active power and 59.56 kVAR of reactive power.

Table 4: Result of Sensitivity Analysis

Sub-Case	Household Demand (W)	P_{Demand} (kW)	Q_{Demand} (kVAR)	P_{Loss} (kW)	Q_{Loss} (kVAR)	Remark
1	200	2602.1	2307.4	53.07	14.36	Insufficient
2	400	5314.9	4638.56	219.90	59.56	Insufficient

In the system there are three main branches. This structure is same as the longest path for each branches and given in figure 2.Figure 3 (i) presents a voltage pu comparison graph for these different branches with respect to distance in km. Each branches have different conductor size and load demands. The voltage pu of all branches decreases with increment in distance. But the decrement rate of voltage pu are different for all of the branches because of the difference in conductor size and voltage drop across them. Higher the conductor size, lower will be the voltage drop. Similarly, the decrement rate decreases with increment of distance, because the current, voltage drop and the losses decreases at the backward branches as shown in figures 4,5 and 6. Generally, increasing the load and load number, the current rating increases in the case of the load center, and load increases with increment of distance. Because of the additive current rate at forwarded branches, the power losses is higher in previous branches than backward branches.

In real case, there is presence of multiple sub-branches in each main branches. The position of load centers in sub-branches may be closer than that of main branches. Similarly, the current rating of that load center in sub-branch is lower than that of main branch resulting fluctuation in voltage pu. For example, node 4 (sub-branch) is closer than node 5 (main branch) as shown in figure 2. But the node 4 is at the end of its sub-branch, while 5 is on the main branch. In this case the voltage pu of node 5 is higher than node 4 because of the high current rating. The curve (ii) shows non-linear nature due to such irregularity in current and load demand of the branches and sub-branches. As shown in figure 2, the sub divided branches are more in branch 3 than on branch 2 with the fluctuation also being higher for those branches. Similarly, the voltage drop in real case is higher because of the higher number of load as well as irregular sub-branches resulting low voltage pu than above case.

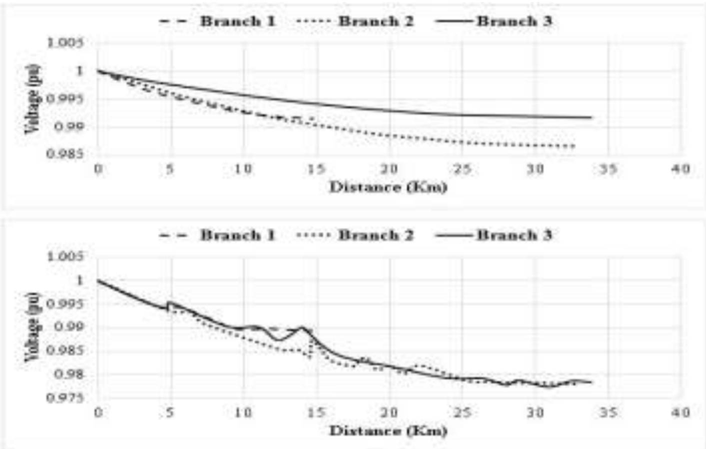

Figure 3: Distance vs. Voltage (pu) for Linear and Real Network Structures

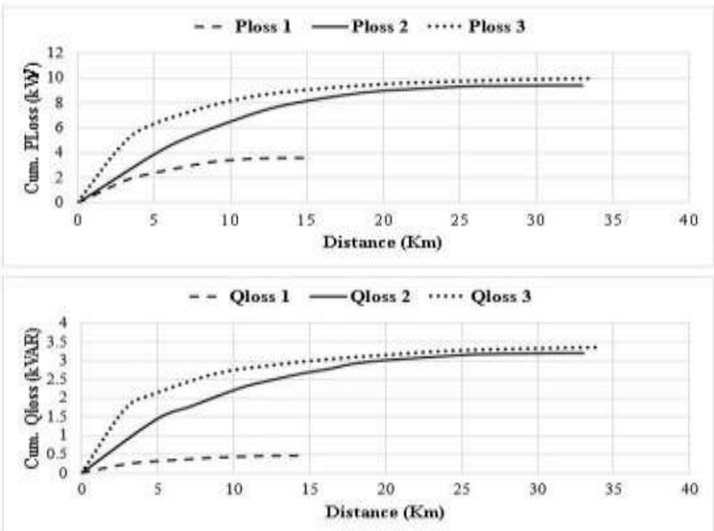

Figure 4: Distance vs. Cumulative Power Losses for Linear Network Structure

Figure 4 shows the characteristics of cumulative active power loss and cumulative reactive power loss with respect to distance. Ploss1 and Qloss1 shows the cumulative active and reactive power loss in branch1 with respect to variation in distance, and so on. This curve shows that the continuous increment of cumulative values with decreasing slope results in the decrement of rate of additive value. The decrement in slope is occurred due to the decrement of current in backward branches. Similarly, figure 5 represents the characteristics of active and reactive power loss per km with respect to distance. By increasing the total distance of a branch, the average power losses will decrease. Also figure 6 shows that, the power loss increases with the increment of the current rating.

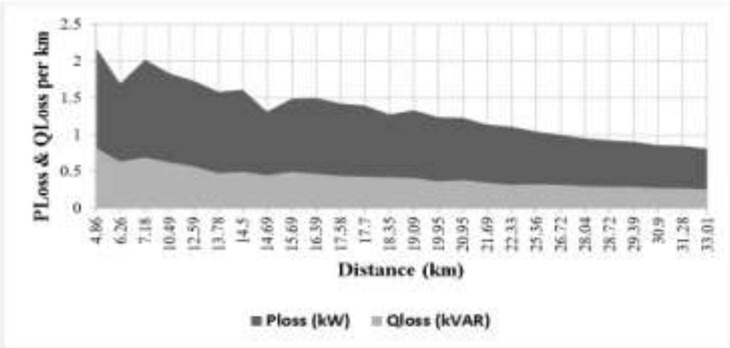

Figure 5: Cumulative PLoss and QLoss per km for Real Network Structure

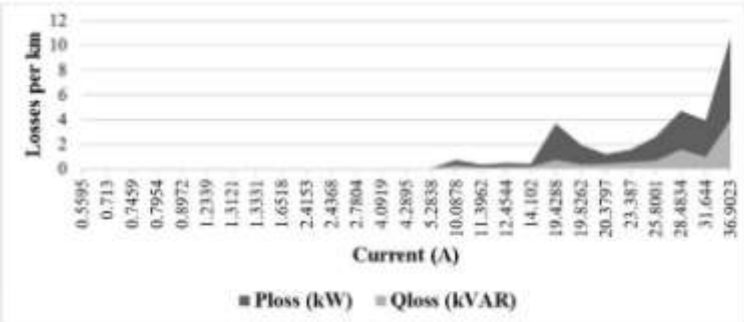

Figure 6: Active and Reactive Losses with Current variation for Real Network Structure

VI. RESULT VERIFICATION

To check the validity of the algorithm and its results, the method had been tested on standard 33-bus radial distribution feeder system [29]. From the case study, a 33-bus radial distribution feeder was considered and LFA was carried out. The results of 33-bus radial distribution feeder system and that of the developed framework for the case area were compared statically. To compare the results of different algorithms, paired sample T-test was performed. The comparative result is given in table 5. As shown in table 5 the standard deviation and standard error mean, which are considered to be important parameters, are very low in both of the paired sample. There is no any significant difference between the results in 95% confidence of interval.

Table 5: Comparative result of different Load Flow Algorithms (Paired Sample T test)

Method Pair	Tested Parameter	Mean	Standard Deviation	Standard Error Mean	95% Confidence Interval of the Difference		Significance (2-tailed)
					Lower	Upper	
NR-Sweep	Voltage (pu)	-0.004	0.005	0.001	-0.005	-0.003	0.000
	Angle (deg)	0.116	0.154	0.020	0.075	0.156	0.000
	Real I (A)	0.587	0.104	0.014	0.031	0.086	0.000
	Imaginary (I)	-0.015	0.023	0.003	-0.021	-0.009	0.000
	Ploss (kW)	0.000	0.001	0.000	0.000	0.000	0.357
	Qloss (kVAR)	0.000	0.001	0.000	0.000	0.000	0.330
NR-Standard 33 Bus	Voltage (pu)	-0.001	0.001	0.000	-0.001	-0.006	0.000
	Angle	0.022	0.017	0.003	0.016	0.028	0.000
	Real I (A)	0.671	0.957	0.167	0.331	1.010	0.000
	Imaginary (I)	-0.585	0.843	0.147	-0.884	-0.286	0.000
	Ploss (kW)	0.116	0.240	0.042	0.030	0.201	0.009
	Qloss (kVAR)	0.040	0.084	0.015	0.010	0.070	0.010

VII. DISCUSSION AND CONCLUSION

To study the performance and characteristics of the system, there are number of approaches, among which load flow analysis is one of the best tool. Among the different techniques of load flow analysis, we found N- R to be one of the best alternative, since it is basic, simple and requires less time for execution compared to other computational analysis. Also, in our case, there was absence of problems related to high R/X value and radial characteristics as occurred in general distribution system. The computational execution were conducted in the standard 33-bus radial feeder system and forward/ backward sweep based algorithm to validate the performance of the framework. Table 5 shows the comparative parameters of the methods, which shows the capability and reliability of the framework for solving the LFA of complex distribution system as well.

Different parameters (conductor, voltage level, voltage regulation etc.) were analyzed during the design of the system and hence an optimized system was developed. The energy loss was calculated to be minimum (2.04 %) for base load demand of 200 W. The pre-defined 2 MW power plant is insufficient to supply the electricity to whole affected area of UKHPP. Other energy sources (Solar/ Wind/ Micro Hydro/ Grid) should be interconnected to meet the peak demand. But, observing the results and its performance at different methods, it was seems to be a stable and reliable distribution system. Further analysis and improvement may be required for the secondary distribution system.

ACKNOWLEDGEMENTS

This study is a part of Energy Access project of Upper Karnali Hydro Power Project, under the Office of the Investment Board Nepal, Government of Nepal. The authors would like to thank all the staff member, faculty of Kathmandu University (Nepal), Office of the Investment Board, Government of Nepal and Frederick University (Cyprus), for their cooperation during this study. The authors would like to acknowledge Mr. Ajay Singh for his support during developing the program in MATLAB software. We are also thankful to Mr. Ravi Koirala, Mr. Ramesh Maharjan and Mr. Anil Wagle for their support and suggestions.

REFERENCES

[1]. (17/11/2016). Distribution System. Available: http://www.nct-tech.edu.lk/Download/Technology%20Zone/Distribution%20Systems%20-%20General.pdf

[2]. "ELECTRICITY REGULATION, 2050 (1993)," Nepal Electricity Authority (NEA)1993, Available: http://www.nea.org.np/images/supportive_docs/Electricity_Regulation_2050-english.pdf.

[3]. N. Smith and G. Ranjitkhar, "Nepal Case Study–Part One: Installation and performance of the Pico Power Pack," Pico Hydro Newsletter, 2000.

[4]. A. Y. Abdelaziz, M. Badr, and A. Younes, "Dynamic load modeling of an Egyptian primary distribution system using neural networks," International Journal of Electrical Power & Energy Systems, vol. 29, no. 9, pp. 637-649, 2007.

[5]. O. A. Afolabi, W. H. Ali, P. Cofie, J. Fuller, P. Obiomon, and E. S. Kolawole, "Analysis of the Load Flow Problem in Power System Planning Studies," Energy and Power Engineering, vol. 7, no. 10, p. 509, 2015.

[6]. A. M. Zaw and H. M. Tun, "Design and Implementation of SCADA System Based Power Distribution for Primary Substation (Monitoring System)," Int. J. Sience, Eng. Technol. Res., vol. 3, 2014.

[7]. L. Kang and L. Yang, "A Distributed and Parallell Computing Framwork for SCADA Application in Power System," in Electrical and Control Engineering (ICECE), 2010 International Conference on, 2010, pp. 2597-2600: IEEE.

[8]. W. F. Tinney and C. E. Hart, "Power flow solution by Newton's method," IEEE Transactions on Power Apparatus and systems, no. 11, pp. 1449-1460, 1967.

[9]. B. Stott and O. Alsac, "Fast decoupled load flow," IEEE transactions on power apparatus and systems, no. 3, pp. 859-869, 1974.

[10]. T.-H. Chen, M.-S. Chen, K.-J. Hwang, P. Kotas, and E. A. Chebli, "Distribution system power flow analysis-a rigid approach," IEEE Transactions on Power Delivery, vol. 6, no. 3, pp. 1146-1152, 1991.

[11]. U. Eminoglu, T. Gözel, and M. Hocaoglu, "DSPFAP: Distribution systems power flow analysis package using Matlab graphical user interface (GUI)," Computer Applications in Engineering Education, vol. 18, no. 1, pp. 1-13, 2010.

[12]. J. M. Rupa and S. Ganesh, "Power flow analysis for radial distribution system using backward/forward sweep method," International Journal of Electrical, Computer, Electronics and Communication Engineering, vol. 8, no. 10, pp. 1540-1544, 2014.

[13]. M. Sedghi and M. Aliakbar-Golkar, "Analysis and comparison of load flow methods for distribution networks considering distributed generation," International Journal of Smart Electrical Engineering, vol. 1, no. 1, 2012.

[14]. J. D. Glover, M. S. Sarma, and T. Overbye, Power System Analysis & Design, SI Version. Cengage Learning, 2012.

[15]. A. Chakrabarti and S. Halder, Power System Analysis: Operation And Control 3Rd Ed. PHI Learning Pvt. Ltd., 2010.

[16]. J. J. Grainger and W. D. Stevenson, Power system analysis. McGraw-Hill, 1994.

[17]. "Nepal Livinf Standard Survey III and Poverty in Nepal (2010/2011)," National Planning Commission Secretariat, Government of Nepal, Kathmandu, Nepal2012 2012.
[18]. "Nepal Population and Housing Census 2011," National Planning Commission Secretariat, Government of Nepal, 20122012 2012.
[19]. "The Hydropower Development Policy, 2001 " Ministry of Water Resources2001 Available: http://www.doed.gov.np/policy/hydropower_development_policy_2001.pdfw.
[20]. A. Shrestha, S. K. Jha, B. Shah, B. R. Gautam, "Optimal Grid Network for Rural Electrification of Upper Karnali Hydro Project Affected Area," in 2016 IEEE REGION 10 Humanitarian Technology Conference (R10-HTC), India, 2016.
[21]. R. Nepal, "Roles and potentials of renewable energy in less-developed economies: the case of Nepal," Renewable and Sustainable Energy Reviews, vol. 16, no. 4, pp. 2200-2206, 2012.
[22]. "Access to electricity % of population," ed: World Bank, 2016.
[23]. (2016). Electric power consumption (kWh per capita). Available: http://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC
[24]. (2016). Renewable Energy Data Book. Available: http://www.nrel.gov/docs/fy16osti/64720.pdf
[25]. "A Year in Review-Fiscal Year 2015/2016," Nepal Electricity Authority, kathmandu, Nepal2016 2016, Available: http://www.nea.org.np/images/supportive_docs/NEA%20design.pdf.
[26]. J. Parmar. (2013). How to calculate voltage regulation of distribution line. Available: http://electrical-engineering-portal.com/how-to-calculate-voltage-regulation-of-distribution-line
[27]. INTERNATIONAL STANDARD (IEC 60439-1), 2004.
[28]. J. Parmar. (2011). Demand Factor-Diversity Factor-Utilization Factor-Load Factor. Available: https://electricalnotes.wordpress.com/2011/10/31/demand-factor-diversity-factor-utilization-factor-load-factor/
[29]. R. S. Rao, K. Ravindra, K. Satish, and S. Narasimham, "Power loss minimization in distribution system using network reconfiguration in the presence of distributed generation," IEEE transactions on power systems, vol. 28, no. 1, pp. 317-325, 2013.