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Foreword

I am delighted to write the foreword for the Volume II of the "Thrue Rig Sar Toed - academic excellence through research and innovation", a publication of Jigme Namgyel Engineering College (JNEC), where selected scholarly works of students and academics are published. Thrue-rig Sar-toed is a humble intent to showcase the scholarly works carried out by students and academics in their respective areas of expertise.

The inaugural volume of the Thrue-rig Sar-toed has been well received and I would like to thank our esteemed readers for your support. Every great thing has a humble beginning, likewise, Jigme Namgyel Engineering College is an academic institution that truly believes in taking baby-steps to be able to finally run and achieve greater heights. The first volume of the publication has given us adequate experience and it is our hope that the second volume will help our researchers gain additional experience and enable them to carry out meaningful research works that have deeper impact on the society. In addition, we hope that our esteemed readers are able to connect better with the papers.

Education that we receive will have no meaning if we are not able to bring about positive changes to the society and the mankind. We must provide education to help the mankind and not to destroy it. Therefore, all research works carried out in the academic institutions must be targeted towards eventually bringing benefits to the society. The second volume features seven papers selected from the 2nd Annual Inter-programme Conference held in Jigme Namgyel Engineering College in 2018.

I would humbly request all readers to continue to support us and provide constructive criticism and feedback to enable us to grow further and contribute towards meaningful research and innovation in the area of applied engineering, technology and management.

I would like to congratulate all researchers for your hard work and contribution and continue to hope that we are able to make humble impacts to the society through this publication.

Tashi Delek!

Karma Drukpa

(Acting President, JNEC)

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Rainfall-Flow Correlation and Flow Trends in Punatshangchu and Kholongchu Basin

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Abstract— Bhutan is a country highly dependent on the agriculture and hydropower sectors. Due to this dependence, it is of utmost importance that the water resources and rivers of Bhutan are regulated for optimum use and sustainability. This research was undertaken to assess the flow trends and the correlation between flow and rainfall. Mann Kendall's coefficient correlation and Sen's slope test were conducted for trend analysis as a non-parametric test and the relationship assessment was done using Pearson's Coefficient of Correlation. From the study, there was no trend observed in any flow gauging station which is apparently due availability of limited flow data. Significant correlation was observed is observed with flow and rainfall at lag 1 for all the flow station, while significant positive correlation was observed at lag 4 for rainfall at Phobjika and flow at Wandgi rapids.

Keywords—Rainfall, Flow, Correlation, MK test, Bhutan.

1. Introduction

Incidental to the development of the country, the advent of natural and man-made climate change externally and internally became much more evident. The demand for the daily necessities of modern life required equivalent exploitation of the natural thriving environment. However, the by-products of human exploitation and interference slowly but surely lead to a pitfall that would prove near cataclysmic for future and present generations. Being a landlocked country with a rugged terrain and exposed to significant climate risks from the melting of glacial lakes, floods, and landslides, it is easily susceptible to global climate change. Erratic rainfall threatens the economy, since hydropower accounts for 40 percent of exports, and rain-fed agriculture provides employment to nearly 60 percent of the population [1].

The current evidences of climate change in Bhutan are primarily extreme weather events, but impacts from incremental changes are likely to be evident in the coming decades. The impacts of climate change depend primarily on the people's vulnerability, which is determined by factors including poverty, remoteness, governance, capacity and awareness, natural resources management and other factors that pose challenges to achieving national development targets [1].

Bhutan has the potential to generate an estimated 23,760 megawatts (MW) of hydroelectric power, but at peak times consumes only 300 MW [2]. With economic and population growth creating a shortage of electricity in India, the RGoB and the Government of India (GoI) agreed in 1974 to jointly construct Bhutan's first major hydroelectric plant. Bhutan's Nationally Determined Contribution (NDC) to the Paris Agreement on climate change indicates its intent to remain carbon neutral. This implies that its carbon emissions, estimated at 2.2 million tons of CO2, will not exceed total carbon sequestration by their forests. Furthermore, the Constitution of Bhutan mandates that the country maintain a minimum of 60 percent of the total land under forest cover. Bhutan's NDC indicates the possibility of offsetting 22.4 million tCO2e (tons of carbon-dioxide equivalent) through the export of hydroelectricity by 2025 [3]

In recent years, the flow formation in a changing environment has become an important scientific problem in hydrology. A better understanding of the flow changes and their potential driving forces are thus of paramount importance to effectively utilize water resources and reasonably manage river flows [4]. Generally, climate change and human activities are significant factors influencing flow variation. And these factors affect the hydrology and water cycle in

a region. In a long-term span, climate change is a dominant factor affecting flow in drainage basins. In a short-term span, human activity interference is the main cause of hydrology process variation in a drainage basin.

Defining temporal change in river discharge is a fundamental part of establishing hydrological variability, and crucially important for identifying climate–streamflow linkages, water resource planning, flood and drought management and for assessing geomorphological and hydro- ecological responses [5].

Costs related to hydropower now constitute approximately two-thirds of Bhutan's external debt, which stood at 99 percent of GDP at the end of 2015. The dominance of hydropower exports as a source of foreign exchange also raises the specter of "Dutch Disease"— that is, the competitiveness of other industries is undermined by the increased competition for resources (such as labor and materials) with the hydropower sector. Currently, imports for hydropower construction constitute half of the country's current account deficit, which stood at 26 percent in December 2016. Moreover, the inherent volatility in hydropower generation—which is likely to increase as climate change affects winter snowfalls and the flow of glacier-fed rivers—could result in large fluctuations in government revenue and expenditure if not properly managed [2]. Considering these challenges, there is an expressed need for Bhutan to address the vulnerability to climate change at the national, local and sectoral levels.

GIS-based drainage morphometric quantification and analysis is found to be a cost-and time-effective approach to characterize poorly gauged basins as an alternative and complementary source of information [6].

Main targets of study are trend analysis, relation of discharge and rainfall. Mann-Kendall test, Sen's slope and correlation have been conducted to achieve these targets. Besides these, monthly variation of rainfall and discharge have been analyzed in this study. Coefficient of variation has been used to find monthly variation. Statistical methods have been conducted to this study [7].

Flow, a component of the hydrological cycle, is considered an important process in the study of hydrology. Knowledge about flow components (surface and channel flow) under changing climatic and vegetation condition in the White Volta River catchment is limited. Information about flow is fundamental to the understanding of part of the hydrological processes in the catchment (White Volta River basin). For instance, flow contributing to stream flow from all parts of the catchment is an important factor in meeting its water volume standards in the main Volta River and Akosombo dam [8].

With the development of the rainfall- flow database we are able to show the uncertainties related to precipitation measurements and forecasts as well as uncertainties related to initial conditions. The results of our studies in the Mulde catchment showed that the generated rainfall scenarios are representing a variety of artificial (or not yet occurred) as well as real rainfall events, capturing a large spectrum of different volumes and intensities. Moreover, we demonstrated that flood events can be captured by the range of the result set of flow simulations [9].

The implications of analytical decisions on the interpretations of hydrological change are important and impact on planning and development in many fields including water resources, flood defense, hydro-ecology and climate-flow analysis. This study also confirms the importance of using the seasonal streamflow data in trend analysis, rather than simple annual means which can sometimes fail to reveal the full temporal complexity of flow trends [5]. Large-scale hydropower has been the main driver and the backbone of Bhutan's economy. Hydropower development plans to 2022 foresee investments totaling USD 3.3 billion for an additional capacity of 3.8 GWe. Revenues from electricity generation already account for an estimated 22% of GDP. Despite Bhutan's political and financial commitment to hydropower development, there is no data available nor any studies planned on the potential negative impacts of climate change on the country's hydrological flows, and existing and future hydroelectricity plants. Run-of-the-river hydropower plants, as constructed in Bhutan, do not operate reservoirs, and are highly dependent on natural run-off, and thus susceptible to climate change and variations [1].

Increasing trend of yearly discharge at Kushiyara River might affect the water demand to meet the needs of growing communities, farmers, energy producers and manufacturers. Irrigation and navigation would be affected severely. Rainfall is decreasing year to year. Irrigational and sedimentation activities will be hampered due to scarcity of rainfall. In winter season, monthly variation of rainfall is maximum than other seasons. So, it needs to take proper plans for replenish the surface water management otherwise surface water condition would be worse [7]. The response of a particular watershed to different hydrological processes and its behavior depends upon various physiographic, hydrological and geomorphological parameters. Though these are watershed specific and thereby unique, the characterization of a watershed provides an idea about its behavior. Geomorphological analysis helps in better understanding of hydrological system of watershed which is useful for carrying out management strategies [10].

The state-led hydropower development yielded an annual average GDP growth rate of 7.6 percent since 1981, the third-highest in the world. The country's power generation capacity increased from 336 MW in 1990 to 1,606 MW in 2015 and has remained the same since then. During the same period, gross fixed capital formation (mainly hydropower investment) contributed to more than 60 percent of GDP growth. Hydropower development is undertaken by Druk Holding and Investments (DHI), which is fully owned by the government. The sector accounted for about 40 percent of exports in 2016 and 25 percent of the total domestic revenues. Benefits of hydropower development have been distributed to the population through increased government spending on health and education [11].

The main objective of this study is to determine flow trend and to study the correlation between rainfall and flow in the two basins.

2. Materials and Methods

2.1. Study Area

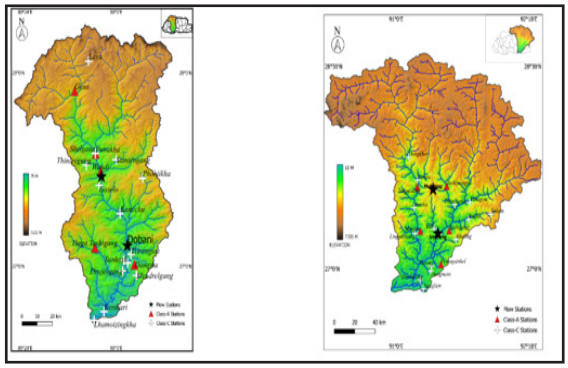

Fig 1 Study area (a) Punatshangchu Basin (b) Kholongchu basin

Bhutan has five main river systems which are Amochhu, Wangchhu, Punatshangchu, Mangdechhu and Drangmechhu. The other five smaller river systems are Jaldakha, Aiechhu, Nyera Amari, Jomori and Merak-Saktengchhu. These river systems also form five major river basins and five smaller river basins. Punatshangchu river basin is the largest basin with an area of 9,645 km2 and represents 25% of the country's total land area [12]. Hydropower plants under construction are Punatshangchu HP I (1200 MW) & II (1020 MW). Punatshangchu Basin is a stream (Class-H Hydrographic) in Asia, Bhutan. It is located at an elevation of 106 meters above sea level. Its coordinates are 26°22'60"N and 89°48'0"E in DMS (degree, minutes and seconds) or 26.3833 and 89.8 in decimal degrees.

Kholongchu, which is a sub-basin of Drangmechhu in eastern Bhutan has the first Integrated sub-basin Management Plan developed since 2017 [12]. The project is located at the lower course of Kholongchu just before its confluence with Drangmechu (Gongrichu) in Trashiyangtse District of Bhutan. The diversion site is located at Latitude 27º 32' 50" & Longitude 91º 30' 49" E.

2.2. Data Collection

The flow and rainfall data were collected from National Centre of Hydrology and Meteorology (NCHM).

Daily time series of stream flow or discharge at

river Punatshangchu with two basins Wangdi rapid and Dobani is taken from 1992-2015 and Kholongchu with two basins Uzorong and Muktirap was taken from 1992-2015 and 2001-2015 respectively was analyzed in this study. Total period of discharge data is 22 years for three flow stations except for Muktirap which is of 15 years. The flow statatistics are as shown is Table 1. In the other hand, daily time series data of Rainfall at Gasa, Lingshi, Pelela, Punakha, Samtengang Shelgang, Thinleygang, Kumichu, Nobding, Phobjkha, Mongar, Kanglung, Autsho, Yadi, Radhi, Dungkhar, Tangmachu and Tashi Yangtse have been analyzed. Time period for rainfall data is 22 years which is from (1992-2015).

Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Digital Elevation Model (DEM) maps were downloaded from the United States Geological Survey (USGS) and used to delineate the basins and calculate the basin parameters.

Table 1 Statistics for flow (in cumecs)

Station	Max	Min	Mean	SD
Uzorong	1541.10	33.75	309.74	252.87
Muktirap	958.44	8.64	64.20	64.23
Dobani	3015.90	62.94	362.45	330.88
Wangdi Rapid	2195.30	0.69	293.60	276.09

2.3. Data Analysis

The geomorphological features of a basin are a description of the various imminent features of its surface and its streams. It is also representative of the relationship between the hydrologic responses of different basins. Using an Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Digital Elevation Model (DEM) of 30m resolution, the geomorphological features of both basins were calculated using Quantum Geographic Information System (QGIS) Geographic Resources Analysis Support System (GRASS) software.

2.3..1. Basin Parameters

The geomorphological properties of the two basins describe the various topological characteristics of its landform (surface) and streams. Each of these characteristics further influence the various shape parameters that are directly or indirectly related to the rainfall and surface flow the particular basin. By defining these factors, an understanding of the basins hydrological response is developed and comparisons can be made.

From Fig 2 it is understood that the two basins have varying hydrological responses. The strikingly similar drainage density value signifies a similar potential of availability of surface water in basin, however, since the area of the Kholongchu basin (21000.53 km2) is higher than Punatshangchu (9703.49 km2) the total surface water would be higher. Dd is a measure of the texture of the network, and indicates the balance between the erosive power of overland flow and the resistance of surface soils and rocks. The factors affecting drainage density include geology and density of vegetation.

The vegetation density influenced drainage density by binding the surface layer and slows down the rate of overland flow, and stores some of the water for short periods of time. The effect of lithology on drainage density is marked. Permeable rocks with a high infiltration rate reduce overland

Table 2 Geomorphological Characteristics of Basins

Geomorphological Features	Punatshangchu	Kholongchu
Area (km^2)	9703.49	21003.53
Perimeter (km)	860.03	1318.81
Length of longest flow (km)	265.91	367.37
Total Length of Streams (km)	1579.07	3271.28
Slope of Basin (Degrees)	28.00	26.61
Slope of Streams (Degrees)	0.15	0.09
Mean Elevation of Basin (masl)	3166.05	3817.96

Table 3: Parameters

Parameter	Definition	Formula	Value
Bifurcation Ratio, R_b	Rb = Nu/ Nu + 1	$R_b = \frac{Nu}{Nu+1}$	-
Length Ratio, R_L	$\frac{Total\ length\ of\ streams\ of\ one\ order}{Total\ length\ of\ streams\ of\ next\ order}$	$R_L = \frac{L_u}{L_u - 1}$	-
Drainage Density (Km/Km2)	$\frac{Total\ length\ of\ streams}{Area}$	$\frac{\Delta l}{A}$	-
Form Factor, F_f	$\frac{Watershed\ Area}{(Watershed\ Length)^2}$	$\frac{A}{L^2}$	<1
Shape Factor, S_f	$\frac{(Watershed\ Length)^2}{Watershed\ Area}$	$\frac{L^2}{A}$	>1
Elongation Ratio, E_r	$\frac{Diameter\ of\ cicle\ of\ Watershed\ area}{Watershed\ length}$	$\frac{1.128A^{0.5}}{L}$	≤1
Circulatory Ratio, C_r	$\frac{Watershed\ Area}{Area\ of\ Cicle\ of\ Watershed\ Area}$	$\frac{12.57A}{Pr^2}$	≤1
Compact Coefficient, C_c	$\frac{Watershed\ Perimeter}{Perimeter\ of\ circle\ of\ watershed\ area}$	$\frac{0.2821Pr}{A^{0.5}}$	≥1
Length of Overland Flow, L_g	$\frac{Total\ length\ of\ streams}{2 \times Drainage\ Density}$	-	-
Sinuosity Index, SI	$\frac{Channel\ Length}{Basin\ Length}$	-	-

flow, and consequently drainage density is low. (Gardiner, 1981)

According to Horton, the bifurcation ratio varies from a minimum of 2 in "flat or rolling drainage basins" to 3 or 4 in "mountainous or highly dissected drainage basins"; it is a parameter used in equations giving the number of streams in a basin. Punatshangchu basin has a bifurcation ratio of 1.67 and Kholongchu has a bifurcation sratio of 3.25, the different values represent different responses to floods during an event of heavy rainfall. The shape factor of Punatshangchu basin is higher than Kholongchu representing a less circular and flow inefficient shape (elongated).

2.3.2 Mann-Kandall (MK) test

It is a non-parametric test for identifying trends in time series data. This research paper uses the XLSTAT software for Mann Kendall trend test. Monotonic

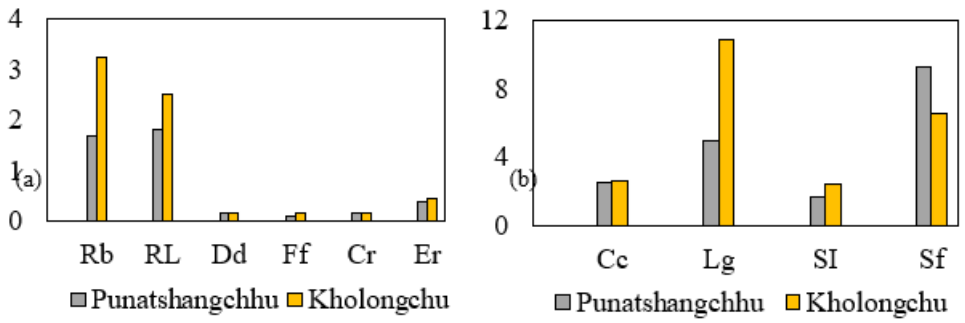

Fig 2 Basin Parameters

trends were analyzed using the non-parametric

Mann-Kendall test [13] (for each of the quantiles of the cumulative streamflow distribution [14]. In this study statistical using Man- Kendall did significance trend analysis test while for the magnitude of trend was determined by non- parametric Sen's estimator method. Man-Kendall test is preferred when various stations are tested in a single study. Mann-Kendall test had been formulated by Mann as non-parametric test for trend finding and the test statistic distribution had been given by Kendall for testing non-linear trend and turning point [15].

The significance level (α) is the probability that a test detects trend or other change when none is present [16]. In this study, the null hypothesis in statistical tests is rejected using α = 0.05. Mann-Kendall statistics (S) is calculated to find out the increasing, decreasing or no trend in data time

series. Each value in the time series is compared with the subsequent data values.

If the earlier value in the time series is greater than the later value, the final value of 'S' would be

positive (an increasing trend). If the earlier value in the series is less than the later value, value of 'S' will be negative (a decreasing trend) and if the value of 'S' is '0' (no trend) in the time series [17].

At 5% significance level, significant increase and decrease in trend of rainfall is considered when -1.96 ≥ Zmk ≥ +1.96, non-significant trends in rainfall is when -1.96< Zmk < 1.96, no trend is considered when Zmk is equal to 0. When Z > +1.96, there is significant increasing trend, while Z <-1.96 indicates significant decreasing trend.

The value of 'S' is calculated as

$$S = \sum_{k=1}^{n-1} \sum_{j=K+1}^{n} Sgn\,(X_f - X_k) \qquad (1)$$

Where,

$$Sgn\,(X_f - X_k) = \begin{cases} 1\ if\ (X_f - X_k) > 0 \\ 0\ if\ (X_f - X_k) = 0 \\ -1\ if\ (X_f - X_k) < 0 \end{cases} \qquad (2)$$

Tied values of either x or y produce a 0 value rather than positive or negative. Tie correction needs to be performed in case there is a presence of tied value.

$$Tie\ correction = \sum_{i=1}^{n} t_i(i)(i-)(2i+5) \qquad (3)$$

Where,

ti = number of repeated values

i = repeated number of values

n = number of data points

In order to statically quantify the significance of the trend in the time series, it is necessary to compute the probability associated with 'S' and the sample size 'n'. The associated probability of 'S' and the sample size 'n' is calculated:

$$V(s) = \frac{1}{18}[n(n-1)(2n+5) - \sum_{i=1}^{n} t_i(i)(i-1)(2i+5)] \qquad (4)$$

Computation of Variance is V(s),

$$Z = \begin{cases} \frac{S-1}{\sqrt{V(S)}}\ IF\ S > 0 \\ 0\ IF\ S = 0 \\ \frac{S+1}{\sqrt{V(S)}}\ IF\ S < 0 \end{cases} \qquad (5)$$

Where,

i = the number of data points in the ith group

n = number of data points

Computation of normalized test statistics, Z.
Where,

Z = Mann-Kendall Statistics

2.3.3 Sen's Slope test

It is necessary to perform Sen's slope estimator test in order to predict the magnitude of the trend.

3. Result

3.1. Trend Analysis using Man-Kendall and Sens Slope test

The null hypothesis of no trend is rejected when S and Z are significantly different from zero. The mean annual flow for the four station mainly Dobani, Wangdi rapids, Uzorong and Muktriap are been statistically analysed in the man Kendall test. The result for the test is the Z statistics of man Kendall test, Sen Slope by manual calculation as shown Table 3 -Table 6. The remark of the result is Mann-Kendall test computes whether the trend is increasing, decreasing or no trend in the time series data. If the trend is increasing, Sen's slope test gives, by what magnitude the trend in the time series data is increasing.

The Sen's estimator predicts the magnitude of the trend. Here, the slope (Qi) of all data pairs is computed as [18].

$$Qi = (x_i - x_j)/(j - i) \quad (6)$$
$$for\ i/= 1.....n$$

Where,

xi-xj = data values at time 'i' and 'j'. (i>j) respectively.

The median (β) of the values of the 'n' values of Qi represented as the magnitude of the trend in the data time series

β = median (Qi (7)

If the p (confidence level) is less than 0.05 (significance value) then, the null hypothesis is true. Statistically significant tests result p less or equal to 0.05 means the test hypothesis is false or should be rejected. Then a p values greater than 0.05 means that no effect was observed. The confidence interval value (equal to zero) will be determined the slope value [19].

The formula for the Pearson product moment correlation coefficient, 'r', is:

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2\sum(y-\bar{y})^2}} \quad (8)$$

all no trend as the positive value of test statistic indicates a positive association means upward trend, negatives value of test statistic indicates a negative association means downward trend and test statistic equal zero means no association (no trend). The test results for the flow of four station are shown in Table 4-7. The result of test is non-significantly decreasing trend while comparing with the Z hypothesis as the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.

3.2. Correlogram Dobani

The correlation is considered significant whose correlation is beyond the threshold represented by a red and grey dashed line known as upper and lower limit respectively and is calculated at a 5% significance level (α = 0.05). The Fig 3 to Fig 13 represents the correlogram associated with flow and rainfall at 10-days lag period. From the figure it is found that for all the flow station, rainfall during the 1st and 2nd day is highly influential

of river flow at the nearest flow gauging station.. However, flow at Wangdi rapids is positively influenced by rain at Gasa by 5-days lag which means the rainwater takes around 5-days to reach Wangdi Rapids. Moreover, it is observed that flow at Dobani is negatively influenced after 4th day of rainfall at Phobjikha indicating significant decline in flow at Dobani after 4th day.

Table 4: Mann Kendall and Sen's Slope test for Wangdi Rapids

Time Series	S	Var(s)	p-value	Kendall's tau	Z-value	Sen's slope	Remarks
Annual	2.00	1625.33	0.98	0.01	0.01200	0.00081	No trend
Winter	24.00	1625.33	0.57	0.09	0.28	0.00142	No trend
Pre-Monsoon	0.000	1625.333	1.000	0	0.000	-0.0009	No trend
Monsoon	16.00	1625.33	0.71	0.06	0.18	0	No trend
Post-Monsoon	36.00	1625.33	0.39	-0.13	-0.86	-0.0159	No trend

Table 5: Mann Kendall Test and Sen's slope for Muktirap

Time Series	S	Var(s)	p-value	Kendall's tau	Z-value	Sen's slope	Remarks
Annual	-19.00	408.33	0.37	-0.18	-0.89	-0.01	No trend
Winter	-33.00	408.33	0.11	-0.31	-1.58	-0.03	No trend
Pre-Monsoon	-20	408.33	0.373	-0.181	-0.940	-0.001	No trend
Monsoon	-12.00	408.33	0.62	-0.11	-0.54	0.00	No trend
Post-Monsoon	-5.00	408.33	0.84	-0.05	-0.19	0.00	No trend

Table 6: Mann Kendall Test and Sen's slope for Uzorong

Time Series	S	Var(s)	p-value	Kendall's tau	Z-value	Sen's slope	Remarks
Annual	-48.00	1625.33	0.09	-0.25	-1.17	-0.02	No trend
Winter	12.00	1625.33	0.90	0.02	0.14	0.00	No trend
Pre-Monsoon	-18.00	1625.33	0.54	-0.07	-0.42	0.00	No trend
Monsoon	-20.00	1625.33	0.64	-0.18	-0.47	0.00	No trend
Post-Monsoon	-42.00	1625.33	0.31	-0.15	-1.0170	-0.2420	No trend

Table 7: Mann Kendall Test and Sen's slope for Dobani

Time Series	S	Var(s)	p-value	Kendall's tau	Z-value	Sen's slope	Remarks
Annual	-56.00	1625.33	0.17	-0.20	-1.364	-0.024	No trend
Winter	104.00	1625.33	0.01	0.38	1.27	0.03	No trend
Pre-Monsoon	-26.00	1625.33	0.54	-0.09	-0.62	-0.01	No trend
Monsoon	-70.00	1625.33	0.09	-0.25	-1.71	-0.04	No trend
Post-Monsoon	-32.00	1625.33	0.44	-0.12	-0.7600	-0.0140	No trend

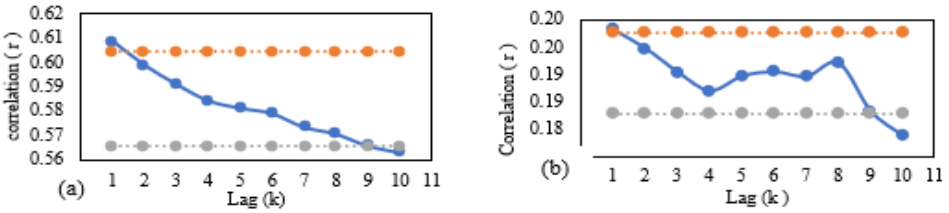

Fig 3 a) Nobding and b) Kamichu

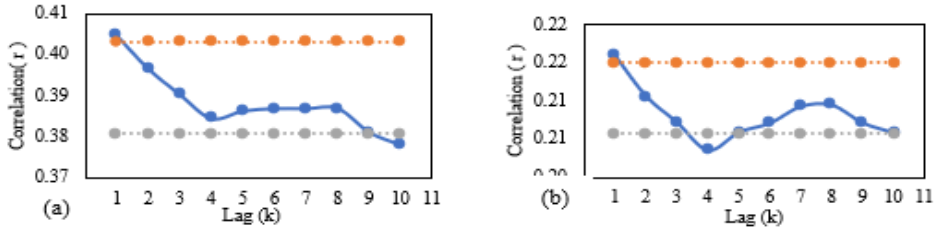

Fig 4 a) Average and b) Phobjikha

3.3 Correlogram Wangdi Rapids

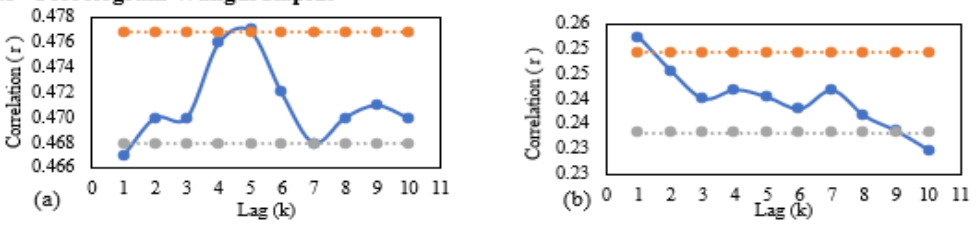

Fig 5 a) Gasa and b) Punakha

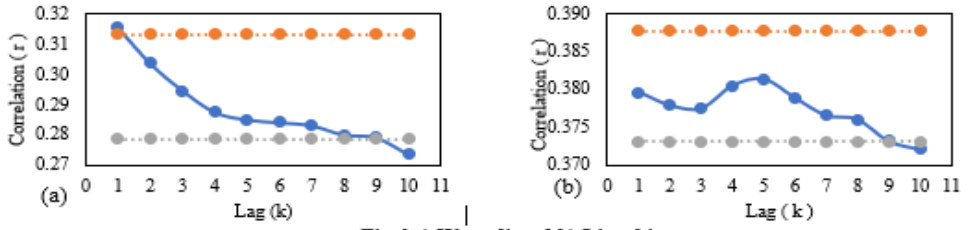

Fig 6 a) Wangdi and b) Lingshi

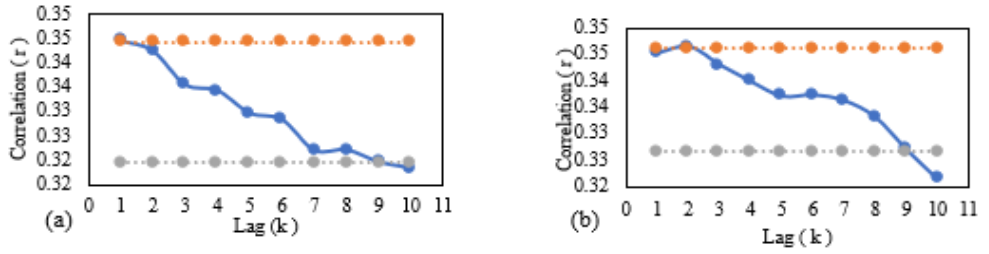

Fig 7 a) Samtengang and b) Shelgana

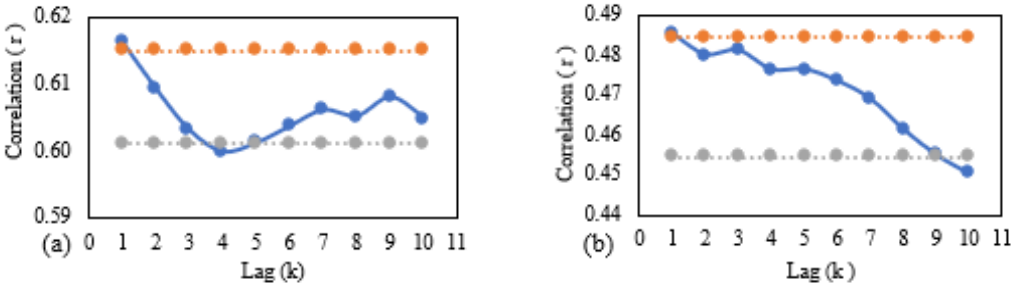

Fig 8 a) Pelela and b) Thinleygang

3.4 Correlogram Muktirap

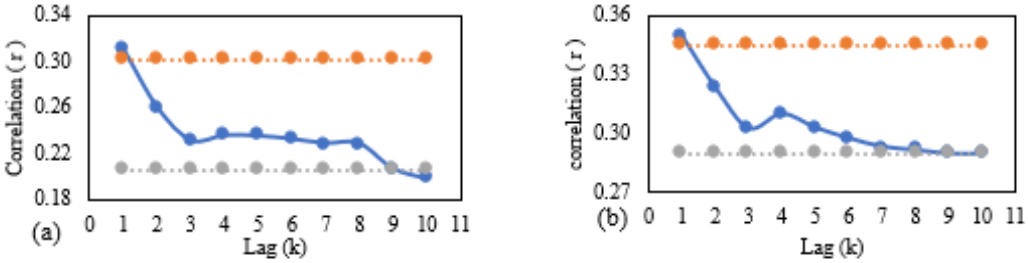

Fig 9 a) Tangmachu and b) Trashiyangtse

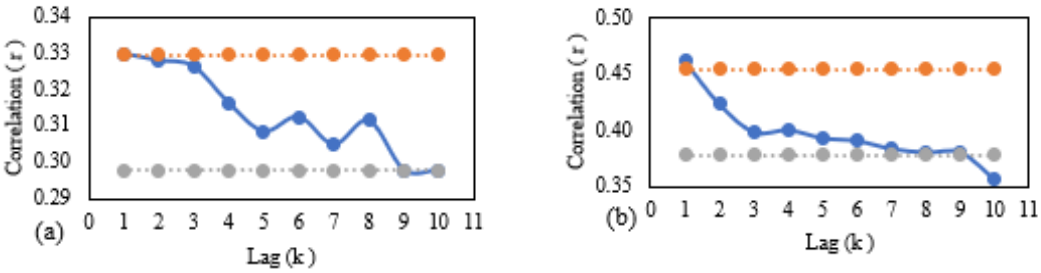

Fig 10 a) Dungkar and b) Average rainfall

3.5 Correlogram Uzorong

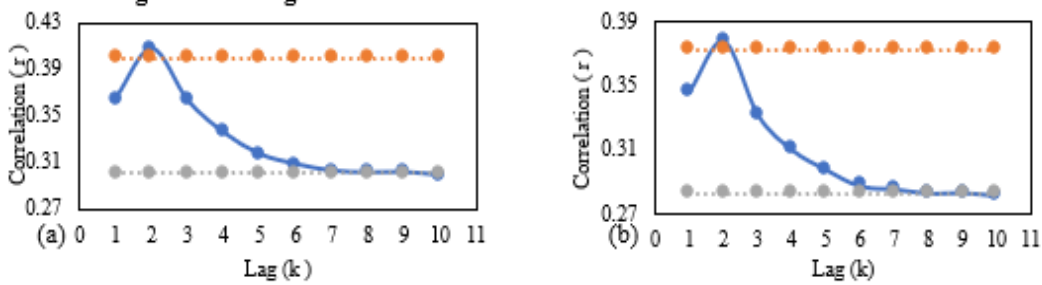

Fig 11 a) Trashigang and b) Autsho

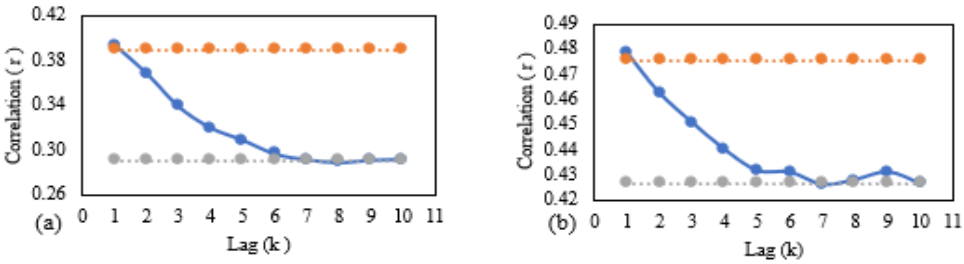

Fig 12 a) Yadhi and b) Radhi

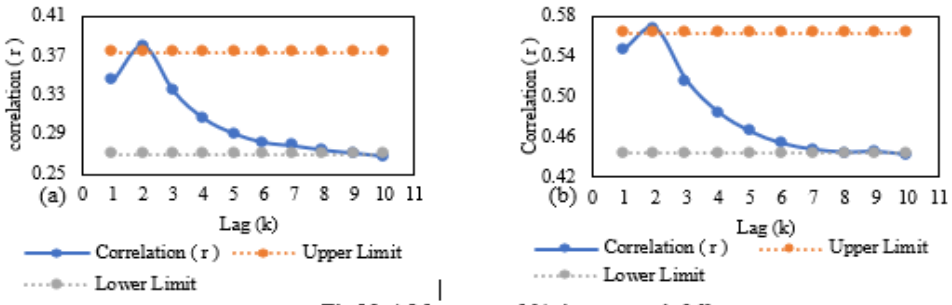

Fig 13 a) Mongar and b) Average rainfall

4. Conclusion

The main objectives of this research are to study the trend analysis in the two basins and to compare the flow regime and rainfall-flow correlation between the two basins. Mann-Kendall trend test, Sen's slope test, Karl Pearson's coefficient correlation was conducted to achieve these objectives. Using GIS tools, certain parameters to compare basin characteristics and how it affected flow for each basin was established.

The different values for various shape factors determined Kholongchu basin to have a higher bifurcation ratio, length ratio and elongation ratio. These higher values for Kholongchu were established by the sheer size of its basin, it can be seen possessing more circularity compared to Punatshangchu. Thus, by examining the features and factors, we find Kholongchu to have a more flow efficient and mature basin.

Correlation performed with rainfall-flow data were all found to be positive, which indicates that rainfall was affecting the flow. The value of coefficient of correlation ranges from 0.3303 to 0.4020 which indicates a moderate positive correlation between rainfall and flow.

From the trend analysis, it was observed that there is no trend in any of the flow station. Such an observation is mainly due to limited data that was under consideration.

The set of data used for this research were of 25 and 15 years for rainfall and flow respectively which are not a significant set of data. The significance level helps in rejecting or accepting the null hypothesis. The significance level of 5 percent indicates risk of concluding that a difference exists when there is no actual difference. There were missing data for which arithmetic mean method was used to fill up those missing data. Better methods can be used for filling the missing data. This research can further be improved with more sets of data. Most of the researchers insists on using minimum of 30 to 50 years of data.

ACKNOWLEDGEMENT

We are deeply thankful to our supervisor, Mr. Vasker Sharma whose help, stimulating suggestion, knowledge, experience and encouragement helped us in all the times of study and analysis of the project in the pre and post period and without whom this report was almost impossible. It was a really good learning experience working under his supervision.

REFERENCES

[1] NEC. "Strategizing Climate Change for Bhutan". National Environment Commission, Royal Government of Bhutan (Issue January), 2018.

[2] Santini, M., Tran, T. T., & Beath, A. "Investment in Climate Assessment of Bhutan". https://doi.org/10.1596/28539 , 2017

[3] Bhutan Climate Fund. (2018). "Bhutan Climate Fund: Concept Note" http://documents.worldbank.org/curated/en/971531538568130794/pdf/Bhutan-Climate-Fund-Concept-Note.pdf, 2018

[4] Xu, Y., Wang, S., Bai, X., Shu, D., & Tian, Y. "Low response to climate change and human activities in a typical karst watershed" SW China. 41571130074, pp. 1–27, 2018

[5] Dixon, H., Lawler, D. M., Shamseldin, A. Y., & Webster, P. "The effect of record length on the analysis of river flow trends in Wales and central England" pp. 490–495, 2006.

[6] Kabite, G., & Gessesse, B. "Hydro-geomorphological characterization of Dhidhessa River Basin". International Soil and Water Conservation Research, Vol. 06, no 02, pp. 175–183. https://doi.org/10.1016/j.iswcr.2018.02.003, 2018.

[7] Uddin, M. E., Akter, S. A., Uddin, M. J., & Diganta, M. T. M. "Trend Analysis Variations and Relation Between Discharge and Rainfall : a Study on Kushiyara River" Journal of Environmental Science and Natural Resources, Vol 10, no. 02, pp. 121-132, 2017.

[8] Kasei, R. A., Ampadu, B., & Sapanbil, G. S. "Relationship between Rainfall-Flow on the White Volta River at Pwalugu of the Volta Basin in Ghana" Journal of Environmental and Earth Science. Vol 03, no. 01, pp. 92-100, 2013.

[9] Liersch, S. and Volk, Martin, "A rainfallrunoff database to support flood risk assessment" International Congress on Environmental Modelling and Software. 38, 2008.

[10] Bansod, R. D., & Ajabe, G. S. "Determination of geomorphological characteristics of Karpri-Kalu watershed using GIS techniques." Journal of Pharmacognosy and Phytochemistry. Vol. 7, no. 1, pp. 1940–1944, 2018.

[11] World Bank Group. "Bhutan development report: A Path to Inclusive and Sustainable Development". https://doi.org/10.1596/31236, 2019.

[12] Wangdi, N., Yoezer, D., Wangchuk, J., Policy, E., Choden, S., & Lead, F. P. "Bhutan Water Facts" Ugyen Wangchuck Institute for Conservation and Environmental Research (UWICER), Department of Forests and Park Services, Ministry of Agriculture and Forests, Royal Government of Bhutan, Bumthang and WWF Bhutan Programme Office, Thimphu. 2018.

[13] Blain, G. C. "Teste de Mann-Kendall: A necessidade de considerar a interação entre correlação serial e tendência. "Acta Scientiarum - Agronomy, Vol 35, no. 04, pp.393–402. https://doi.org/10.4025/actasciagron.v35i4.16006, 2013

[14] Karpouzos, D., Kavalieratou, S., & Babajimopoulos, C. "Trend analysis of precipitation data in Pieria Region (Greece)." European Water, pp. 31–40, 2010.

[15] Mondal, A., Kundu, S., & Mukhopadhyay, A. (2012). "Rainfall trend analysis by Mann-Kendall test : a case study of North-Eastern part of Cuttack district , Orissa." International Journal of Geology, Earth and Environmental Sciences, vol. 02, no.01, pp. 70–78, 2012.

[16] Lavado Casimiro, W. S., Ronchail, J., Labat, D., Espinoza, J. C., & Guyot, J. L. "Analyse de la pluie et de l'écoulement au Pérou (1969–2004) : Bassins versants du Pacifique, du Lac Titicaca et de l'Amazone." Hydrological Sciences Journal, Vol. 57, no. 04, pp.625–642. doi.org/10.1080/02626667.2012.672985, 2012

[17] Taxak, A. K., Murumkar, A. R., & Arya, D. S."Long term spatial and temporal rainfall trends and homogeneity analysis in Wainganga basin, Central India" Weather and Climate Extremes, vol. 04, pp. 50–61. https://doi.org/10.1016/j.wace.2014.04.005, 2014.

[18] Sen, P. K. "Estimates of the Regression Coefficient Based on Kendall's Tau". Journal of the American Statistical Association, Vol. 63, no. 324, pp.1379–1389. https://doi.org/10.1080/01621459.1968.10480934, 1968

Corporate Social Responsibilty: A Casestudy at SD Eastern Bhutan Coal Company

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Abstract- Corporate Social Responsibility (CSR) is a term which recently became very popular. It represents an individual's, or an entity's responsibility towards the benefit of community. There is no longer merely profit consideration. Today communities around are demanding that firms take care of them and the environment in which they operate. Corporate Social Responsibility is, in simple words, a way of doing business by combining economic benefit with environmental sustainability. Companies can contribute to the environment in many ways, including: environmental protection, investment in social, educational, or cultural programs, or the return on human resources employed. This paper analyzes the role of CSR and the initiatives taken by one of the companies that is the SD Eastern Bhutan Coal Company Limited located in Samdrup Jongkhar District, towards ensuring Corporate Social Responsibility.

Keywords: Corporate Social Responsibility, Community, Environment Sustainability

1. INTRODUCTION

In last few decades the concept of Corporate Social Responsibility has grown exponentially. The CSR activities are treated as an investment not as a cost where it shows the relationship between organization and the stakeholders. The business' purpose is not only to earn profit but also to look after the welfare of the society. By practicing CSR, companies can be conscious of the kind of impact they are having on all aspects of society, including economic, social and environmental. To engage in CSR means that, in the ordinary course of business, a company is operating in ways that enhances society and the environment, instead of contributing negatively to them. As important as CSR is for the community, it is equally valuable for a company. It is important to both consumers and companies. For a company to be socially responsible, first they need to be accountable to itself and its shareholders. Companies that adopt CSR programs have grown their business to the point where they can give back to society. Thus, CSR is primarily a strategy of large company and also more visible and successful. The more responsibility it has to set standards of ethical behavior for peers, competition and industry.

In general, social responsibility is more effective when a company takes it on voluntarily, as opposed to being required by the government to do so through regulation. Social responsibility can boost company morale, and this is especially true when a company can engage employees with its social causes. They should adopt policies that promote the well-being of society and the environment while lessening negative impact on them. Companies can act responsibly in many ways, such as promoting volunteering, making changes that benefit the environment and engaging in charitable giving.

It contributes to a positive image of the company, increase employees and customer's satisfaction as well as the other factors that need to be consider when measuring business success. This is the question why there is a need for a corporate social responsibility in today's era? If the company is running in well manner, what suddenly happened that the corporate entity feel the need of Corporate Social Responsibility. The current need, emergence of corporate social responsibility and the status of social responsibility are the answers of these questions. Therefore, this study expects to examine the role of Corporate Social Responsibility activities of SD Eastern Bhutan Coal Company Limited in a company and its impact on the communities around.

2. LITERATURE REVIEW

Corporate Social Responsibility is a self-regulating business model that helps a company be socially accountable to itself, its stakeholders and the public (Chen, 2020). The concept of social responsibility proposes that a private corporation have responsibilities to society that extent beyond making a profit (World Business Council for Sustainable Development, 1999). Through displaying the ideals and interests of the organization by charitable involvement, workers can feel motivated (and supported) in finding creative and improved forms of performing their work (Russell, 2018). In the 21st century larger firms face large number of changes and challenges including the CSR as being one of the key problems as firms being not able to satisfy the needs of the society. According to Environment Management (2017), CSR is the continuing commitment by business to behave ethically and contribute to economic development while improving the quality of life of the workforce and their families as well as of the local community and social at large. CSR activities can help forge a stronger bond between employees and corporations and help both employees and employers feel more connected with the world around them (Lumen Learning, n.d). As per Lhaden, (2010) CSR should not only be a moral responsibility but should also have a legal obligation whereby the interests of the people at large are protected from possible abuse. Managing risk is a significant corporate obligation specifically on the environment and other corrupt practices which will have serious implication on the company's reputation that can be reduced by CSR activities (Epstein, 2012).

3. METHODOLOGY

3.1. Respondents

The research participants were 36 altogether, 20 employees of SD Eastern Bhutan Coal Company and 16 local residents of Rishore including the Gup of Dewathang gewog.

3.2. Research Design

Survey was conducted with employees of SD Eastern Bhutan Coal Company limited and interviewed the people of Rishore to collect data. This technique is more reliable and objective.

3.3. Data Collection

Data were collected both from primary and secondary sources. Primary source included self-administered questionnaire framed to collect the required data regarding the perception of the employees towards CSR and financial performance. Secondary source included literature review on corporate social responsibility.

3.4. Data Analysis

To understand the employee's perception on CSR, self-administered questionnaire was analyzed using chi-square test and percentage analysis. Analyzed data are presented in graphs and tabular form.

4. RESULT AND DISCUSSION

A. Perception of local community on the CSR initiatives taken by the company

The people living in Rishore community were surveyed to know their perceptions on CSR benefits provided by the company. The aim was to conduct the survey with local people on their view on the CSR initiatives provided by the company. There were 16 respondents, with 15 local households and the Gup of Dewathang. The results are provided below with percentage analysis on the answers provided by the respondents.

Figure 3.1 Company's initiatives

This pie chart show that 62.5% of respondents agreed that company takes initiatives to reduce environmental impact while 12.5% of respondents disagreed with statements whereas 25% of respondents were not sure about it.

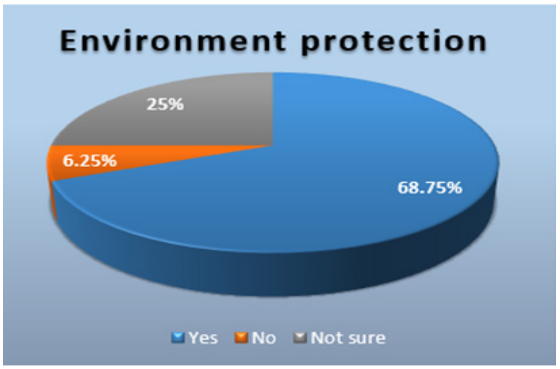

Figure 3.2Environment protection

From this pie chart it can be observed that 68.5% of the respondents agreed that company tries to protect environment while 6.25% of respondents disagreed with statements whereas 25% of respondents were not sure about it.

B. Perception of the employees on relation to CSR and Financial Performance

In order to gain better insight into the CSR initiatives taken by the company, we conducted survey in the form of questionnaires and distributed to the employees of the company. The variables taken were CSR motives, organization benefits and employee's benefit in relation to Corporate Social Responsibility. The results are interpreted using Chi Square test and represented in Likert scale below.

1) Chi Square Test

Chi-square is a statistical test commonly used to compare observed data with data we would expect to obtain according to a specific hypothesis. The formula for calculating chi-square is

$$X^2 = \sum (O - E)^2 / E$$

That is, chi-square is the sum of the squared difference between observed (o) and the expected (e) data (or the deviation, d), divided by the expected data in all possible categories.

TABLE 1

CSR Motives

Chi Square Test	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total
Observed Numbers (O)	12	27	67	93	41	240
Expected Numbers (E =240 /5)	48	48	48	48	48	240
(O-E)	-36	-21	19	45	-7	0
(O-E) ^2	1296	441	361	2025	49	4172
(O-E) ^2/E	27	9.18	7.5	42.18	1.02	86.88

The chi square value is 86.88 and to find degree of freedom we used given formula which is ((r-1) *(c-1)) is equal to (12-1) *(5-1) = 44. After finding degree of freedom, we used chi square calculator to find the P value 0.0001239 which is less than the significance level (0.05). Therefore, employee's perception of CSR practices and CSR motives have a positive relationship.

TABLE 2

Organizational benefits

Chi square test	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total
Observed numbers (O)	10	23	60	95	46	234
Expected number (E=234/5)	46.8	46.8	46.8	46.8	46.8	234
(0-E)	-36.8	-23.8	13.2	48.2	-0.8	0.0
(O-E) ^2	1354.24	566.44	184.96	2323.24	0.64	4429.52
(O-E) ^2/E	28.93	12.1	3.95	49.64	0.0136	94.63

The chi square value is 94.63 and the degree of freedom is 44. By using chi square calculator to find the P value which is equal to 0.00001449 which is less than the significance level (0.05), this can include

that employee perception of CSR practices and organizational benefit have a positive relationship.

TABLE 3

Employee's commitment

Chi Square Test	Unimportant	Of little importance	Moderately important	Important	Very important	Total
Observed Numbers (O)	4	13	26	25	12	80
Expected Numbers (E=80/5)	16	16	16	16	16	80
(O-E)	-12	-3	10	9	-4	0.0
(O-E) ^2	144	9	100	81	16	350
(O-E) ^2/E	9	0.56	6.25	5.06	1	21.87

The chi square value is 21.87 and the degree of freedom is equal to 12. By chi square calculator to find the P value is equal to 0.039 which is less than the significance level (0.05), hence this can prove that employee perception of CSR practices and their commitment have a positive relationship.

2) Percentage Analysis

A pie charts displays data, information, and statistics in an easy-to-read 'pie-slice' format with varying slice telling you how much of one data element exists. The bigger the slice, the more of that particular data was gathered.

The above pie chart explains the percentage analysis which is done using the data from the questionnaire for CSR motives. A calculation based on the CSR motives is based on the data given above the pie chart. It depicts that 38.75% of the employees agrees and 17% strongly agrees with the statements which states the reasons why company is providing CSR that is mainly to strengthen the financial position in the market. Which means more than half of the employees agrees that providing CSR has an impact on the financial performance. And 5% of the employees disagrees that company provides CSR in order to improve the financial performance. Over all maximum of the employees agrees that company providing CSR has a positive impact on the financial performance?

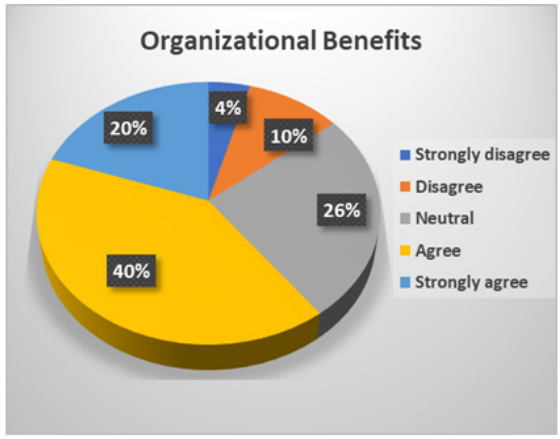

Figure 3.7 Percentage analysis on organizational benefits

The above pie chart explains the percentage analysis which is done using the data from the questionnaire for Organizational Benefits. A calculation based on the organizational benefits is based on the data given above the pie chart. It depicts that 40% of the employees agrees and 26% strongly agrees with the statements which states the benefits that company enjoys after having provided CSR. Which means more than half of the employees agrees that company providing CSR has benefited it financially. And 10% of the employees disagrees which means Over all maximum of the employees agrees they do not agree that company providing CSR has financial benefits. Although, overall, 10% of the employees disagrees more than half of the employees feels that providing CSR has financial

Figure 3.8 Percentage analysis on employee's commitment

benefits towards their organization.

The above pie chart explains the percentage analysis which is done using the data from the questionnaire for Employee's Commitment. A calculation based on the employee's commitment is based on the data given above the pie chart. It depicts that 31% of the employees finds important and 15% very important with the statements which states the employee's commitment towards the organization which provides CSR ultimately having an impact on the financial performance. Although 5% of the employees finds unimportant and 16% finds of little importance, maximum of the employees still feels that they are more commitment towards the organization which provides CSR which ultimately impacts on the financial performance

C. CSR initiatives undertaken by the company towards local community

Over the past few decades and initially from the time of commencement, SD Eastern Bhutan Coal Company limited has played social-economic development roles in its own little myriad ways. The ensuing each year has begun to receive more and active participation than the former ones. The social perimeters of benefits have stretches; starting from uplifting the destitute and economically backward sections of the people; employment generation, financial assistance for pursuing and fulfilling younger generation's education dream. Moreover, it has extended its social donation perimeters to preservation and promotion of culture, games and sport and has continue participation maintained in the times of nation hues and cries (SD Eastern Bhutan Coal Company Limited, n.d.).

On July 8th the project members along with our project guide had a visit to Rishore (community near the company) to survey the residents of Rishore on the CSR initiatives taken by company for the community. It is observed that there were aged population whose wellbeing are being taken care by providing land and also financial supports. The company has notable financial anticipation in reviving razed houses to its normal structure after the natural disaster. The company is committed to a sustainability policy that emphasizes the preservation of the environment. In addition to the stringent environmental standards the company also implements various measures to minimize the effect on the environment. Among these measures taken, is the company initiates and participates in plantation of trees in barren and deforested areas. On land destruction caused by the company, they planted saplings.

As one of the largest manufacturing plants in the Eastern part of the country, the company has always considered its social obligations a primary responsibility. In that regard, a majority of the company's employees are Bhutanese citizens who are trained extensively and develop different skills. In this manner, the company shows its commitment to improving the human resource capacity in Bhutan (SD Eastern Bhutan Coal Company Limited, n.d.). The Company compensated more than Nu 1.7 M to five affected villagers of Rishor chiwog under Dewathang Gewog in Samdrup Jongkhar for the local community, and provided paid internships for students on their vacations (Wangchuk, 2020). To encourage outstanding children of farmers in pursuing higher studies the company introduced donating of financial assistance every year so that it encourages them to fulfill their dream of achieving academic excellence. This effort has motivated children to excel in their studies and spread education in rural areas. Company's main motive is to see an educated, talented and strong youth in the future and thereby contribute towards nation building. The company also provided free transportation for students residing in Rishore Bhutan (SD Eastern Bhutan Coal Company Limited, n.d.).

As per the people residing in Rishore, construction of road was indeed a blessing for them. They say that the company tried to save trees in nearby area to protect the environment. The company has also taken various initiatives by promoting awareness among truckers on the safety in driving and concern for the community. According to the residents of Rishore, the company also benefited them by providing job opportunities that has improved their living standard. Some of the residents were found undertaken business and other enterprising activities in the area.

D. How do internal CSR affect employees' inspiration and confidence?

Engagement of corporate social responsibility is not voluntary any longer. Organizations will recognize that their internal (employee participation, efficiency, attrition rate) and external (increased sales, customer loyalty, brand awareness) success are influenced by CSR. Through developing and investing in CSR programs, organizations have the ability to highlight their core beliefs and develop trust in their staff and customers.

Through research we found out that the company through the promotion of corporate social responsibility (CSR) is reaping the benefits of their good deeds, including increased brand awareness and employee satisfaction. The way a firm treats its community says a lot about how a business treats its employees. People who feel respected and supported in their jobs are often more productive at work and more satisfied. Giving opportunities for your employees to volunteer, especially during working hours, creates a sense of community within your organization as well as a connection to the community around you. Via such professional growth programs, the staff will achieve inspiration and confidence in their jobs. Employees should be encouraged to continue contributing to the larger picture through this social engagement. We can come up with new ideas about goods or internal procedures, or invent new approaches for problem solving.

Employees are no longer focused solely on the benefits that you offer which benefit them directly, such as on-site workout facilities, health benefits etc. It is important to them that you take steps toward social responsibility and do as much as you can to reduce your impact on their personal lives, communities, resources and the entire environment. The objective of a successful CSR system and employee happiness not only resides in how the public perceives you. It's not all about having exterior changes and becoming a successful company neighbor. You ought to support the workers develop and become more, better skilled citizens.

CSR policy is at the heart of the day-to-day operations of the business and guides future progress. We find out that there are a variety of forms the business profits from such endeavors. CSR is known for having an impact on staff turnover. Socially conscious practices foster justice and in effect contributes to lower turnover of employees. On other hand, if a company exhibits an unethical conduct, workers will find such activity to be negative. It is often shown as well-paying workers with fair wages and decent health is viewed as a socially conscious action and therefore decreases the turnover of employees. A supportive work climate may contribute to good outcomes such as more favorable workplace behaviors and improved job efficiency.

5. CONCLUSION

From the findings of the research, it can be seen that CSR initiative is undertaken by company and it has benefited to the people. This research also revealed that social responsibility is regarded as an important business issue irrespective of the size, sector, age, or location of the organization. It can be observed that there is positive relationship between CSR practices and organizational benefit where P value (0.00001449) is less than the significance level (0.05) which is proved using Chi Square test. When it comes to CSR practices and employee's commitment, there is positive relationship where P value is equal to 0.039 which is less than the significance level (0.05).

Through literature review, it can be seen that CSR is undertaken by companies for various reasons. Some of the reasons may include improving their brand image, however, through discussion and findings it is found that although there might be financial gain in such activity, it is more about taking initiatives for the benefit of society and environment. As per the survey done on local community's perception on initiatives taken by company as a part of corporate social responsibility, 75% of the respondents agrees that the company carried out its responsibilities fruitfully.

6. ACKNOWLEDGMENT

The study was carried out for a period of six months research work carried out at Jigme Namgyel Engineering College during which we were supported by our Project Guide Mr. Karma Drukpa, Co-Guide Mr. Ngawang Namgyel and faculty under the Department of Humanities and Management

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7. RECOMMENDATION AND FUTURE SCOPE

Opportunities are endless on how the company can contribute towards achievement of corporate social responsibility. Through findings, it is learnt that the identified company is actively carrying out its corporate responsibilities, however there several issues that the company look into resolving especially reviving environmental concerns as well the maintaining the landscape for the people living around Rishore. The study is limited certain community to assess the impact of Corporate Social Responsibility undertaken by SD Eastern Bhutan Coal Company Limited without indepth study on the various aspects of CSR at broader level. The purpose of the study was to determine activities undertaken as a part of CSR and to observe whether the people were satisfied with the facilities being provided. The survey also offered opportunities for respondents to provide their own ideas and comments. In the period of four months, study could capture certain information from the limited community.

8. REFERENCES

Chen, J. (2020, Feb 22). Retrieved from https://www.investopedia.com

Chew, P. K., & Nasruddin, D. (2015). Corporate Social Responsibility. Retrieved from eprinits.usm.my: https://wwwckpeng-2015-eprints.usm.my

Das, L., & Bhunia, A. (2016, july 19). The impact of CSR on Firms' Financial performance. Retrieved from American journal of Business, Economics and Management: https://www.openscienceonle.com

Epstein, J. (2012, Feb 21). six reasons companies should embrace CSR. Retrieved from Forbes: https://www.forbes.com

Environment Management (2017). Science and Engineering for Industry. https://www.sciencedirect.com/topics/earth-and-planetary-sciences/corporate-social-responsibility

Lumen Learning (n.d). Module 15: Sorporate social responsibility. Human Resources Management. https://courses.lumenlearning.com/wmopen-humanresourcesmgmt/chapter/what-is-corporate-social-responsibility/

Mishra, S., & Suar, D. (2010, september). Does corporate social responsibility influence firm performance of indian companies? Retrieved from ReseachGate: https://www.researchgate.net

Russell, K. (2018). Four benefits of corporate social responsibility. Retrieved from Fronetics: https://www.fronetics.com

SD Eastern Bhutan Coal Company Limited. (n.d.). Retrieved from https://www.sdbhutan.bt

Stawiski, S., Deal, J. J., & Gentry, W. (2010, june). Employee perception of corporate social responsibility. Retrieved from center for creative leardership: https://www.ccl.org

Story, J., & Neves, S. (2014, December 11). when corporate social responsibility increases performance. Retrieved from Wiley Online Library: https://www.onlinelibrary.wiley.com

Lhaden, T. (2010). Corporate social responsibility of the pblic sector entities in Bhutan. https://core.ac.uk/download/pdf/213853129.pdf

Wangchuck. (2009, September 13). Retrieved from https://www.beautifulbhutantour.blogspot.com

Wangchuk, K. (2020, April 24). SD easten Bhutan Coal company compensates more than Nu.1.7 M to affected villagers. Retrieved from BBS news: https://www.bbs.bt

Student Reporting and Verification System for JNEC

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Abstract - Student reporting and Verification System is a web-based application that enables users to register students in a semester and generate student report for a semester. This project ensures to minimize time and resources consumed during manual registration of the student. It will help in generating student reported and not reported for the particular academic semester. This system will be used by student administration to record student status in the system. The system was developed using HTML, CSS, and PHP. This system can be further upgraded by adding user chat features, developing biometric information system and self-registration system in near future.

I. INTRODUCTION

Academic institutions enroll students and it is observed that registration process demands huge manual works. It involves registering new enrolls manually and the lengthy list needs to be compiled to analyze total student registered, reported and not reported. This demands time and energy for person involved in the task. Therefore, this project aimed to develop an online system for student registration and reporting process.

Student Reporting and Verification System is an online system to store the information about the student attending higher education for a particular semester and recording individual students report status during the registration. With the need of, this project expects to develop an effective and efficient system that can automatically generate the report and show the data of students who have registered and who are not.

By using this system, it will assist colleges to maintain the record of the student reported and not reported for a particular semester. Moreover, this system is a solution to minimize the time consumed while maintaining the records of the students reported and not reported.

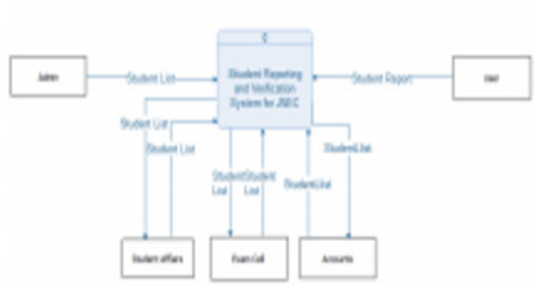


Figure 1: Context Diagram

II. AIM AND OBJECTIVES

Design and develop a management system to generate a report on total student registered for a semester.

Objectives:

- Reduce the workload of the registration personnel.
- Minimize time consumed as compared to manual registration.
- Reduce the wastage of resource.

III. LITERATURE REVIEW

Student Registration System is a software to manage registration operation for a university. This registration system provides a simple set-up of programs for student enrollment. It enables colleges or universities to supervise the growing number of enrollments, reducing the work and costs involved by getting rid of paper and printing resources [1]. The Student Registration System serves to eliminates time and resource wastage. It helps in overcoming the human errors and a time-consuming process.

In another hand, Student Reporting and Verification System provides the same level of function as Student Registration such as time and resource management. However, in this system, it can generate report on the total number of students reported and not reported which Student Registration System lacks.

The Online Reporting System is a Web-based system that provides administrators, teachers, and parents with the information to measurably improve student language proficiency. [2]. This system focuses on the improvement of the student academic which can be viewed by the parents. Whereas Student Reporting and Verification System focuses on generating total number of students reported and not reported which can be viewed by general user who has the user credentials. These two systems work in same field to benefit the colleges but focuses on different section.

Student Reporting and Verification System was developed to serve the need of the college to generate the total number of students reported and not reported dynamically.

IV. METHODOLOGY

Student Reporting and Verification System was developed using "Traditional Waterfall Model". The process starts with Requirement Gathering and Analysis, System Design, Implementation and Testing, Development of system and Maintenance.

Figure 2: Traditional Waterfall Model

1. Phase I

All the requirements regarding Student Reporting and Verification System for JNEC are collected in this phase. For this system, the various requirement was gathered through internet and interview the focal person.

2. Phase II

Design and coding of Student Reporting and Verification System for JNEC was made in this phase. Mockup software was used to design the interface.

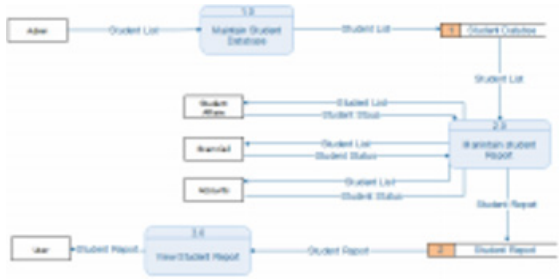


Figure 3:DFD Level 0

Figure 4: ER Diagram

3. Phase III

To implement the interface designed in the earlier phase, PHP, CSS, HTML, JAVASCRIPT was used. Then each work done was reviewed and tested in each phase. Some test is yet to be implemented.

4. Phase IV

The system was developed but it is not yet deployed to use publicly. In fact, the system is deployed on the computers for time being. Accordingly, certain test is performed.

5. Phase V

After the system is deployed publicly, there is chances of bugs or errors. For that, maintenance is yet to be done.

V. RESULT

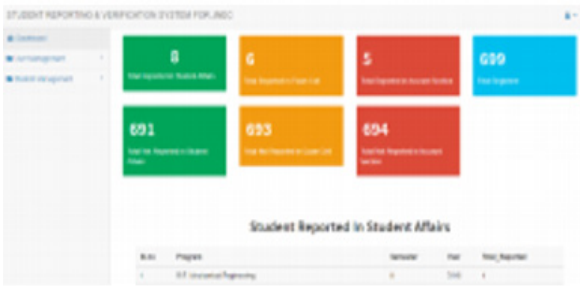
The key interest of this project is to serve the need of student registration team while enrolling new students in terms of shortening time and resources management. The current process of registration was time consuming for both the administrator and student, and required manual generating of the report status. However, this system aims to ease the college management by generating total number of students reported and not reported dynamically.

Login page

This is the login page for the Student Reporting and Registration System for JNEC:

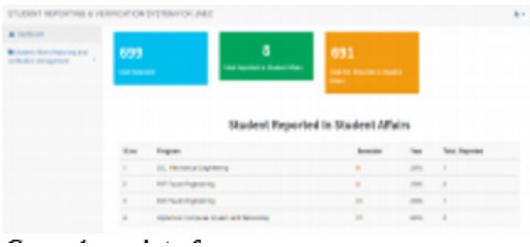
Add, Modify and Delete student and user

Only the admin can add, delete and modify the student and user details.



Fetch and Update student Details

Student Affairs, Exam cell and Accounts can fetch the student details from the database and make necessary modification on it.



General User

General user can be anyone who has user credentials. On login, general user can view the list of reported and not reported student.

VI. CONCLUSION

Student Registration and Reporting System, an online system has been developed to serve during registration process. It focuses to reduce the time taken by the person in charge of generating student registration report and generate the report automatically at the end of registration process. It is indeed a needed application to function the registration process of any colleges.

The system developed provides the users to make required changes during registration, generate registration report automatically and enable the Head of the colleges to view the report. Only admin and designated users can access their specific data. The system is developed with full security from unauthorized access and it is also user friendly, compatible with mobile and considered reliable. This system can be upgraded by adding user chat feature, developing biometric technologies-based registration and reporting system, and self-registration system.

VII. ACKNOWLEDGEMENT

We would like to firstly acknowledge our heartfelt gratitude to Project Guide, Mr. Younten Tshering for his guidance and support in making our project a successful one. We, also extend our gratitude to project coordinator Ms. Sonam Wangmo for her timely advice, supervision and monitoring our project and its progress. We are also grateful to Senor ICT Officer, Mr. Sonam Jamtsho and Mr. Sangay Tenzin, a faculty of IT Department for review and valuable recommendation.

We are indeed thankful to the Department of IT for assuring all necessary support at the time of need.

VIII. REFERENCES

[1] S. Atheer, "Definition of Student Registration System," 16 April 2014. [Online]. Available: https://prezi.com/pb_h4w6fvuhw/definition of-student-registration system/?frame=46f7f6e1fba6862869e8b9f7f93b986698f04582.

[2] "Online Reporting System," 20 2 2000. [Online]. Available: https://terranova3.com/online-reporting system/.

Accuracy Assessment of Digital Elevation Models for a Mountainous Terrain

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Abstract - Digital elevation models (DEMs), which can occur in the form of digital surface models (DSMs) or digital terrain model (DTMs), are widely used as important geospatial information sources for various remote sensing applications, including, the precise orthorectification of high-resolution satellite images, 3D spatial analyses, multi-criteria decision support systems, and DEM is also commonly used for hydrological and geological studies and geomorphological studies. The accuracy of DEMs has direct impacts on specific calculations and process chains; therefore, it is important to select the most appropriate DEM by considering the aim, accuracy requirement, and scale of each study. In this research, DEMs obtained from a variety of satellite sensors were compared with 20 Ground Control Points (permanent GCPs) and 380 elevation points within the Jigme Namgyel Engineering College boundary to analyze their accuracy and performance. For this purpose, freely available Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Shuttle Radar Topography Mission (SRTM), and Advanced Land Observing Satellite (ALOS) of 30m resolution data were obtained. The purpose of this study is to assess the accuracy among the three DEMs. The vertical accuracy of DEMs is evaluated through six performance indicators coefficient of correlation (r), coefficient of determination (□2), Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Nash-Sutcliffe Efficiency (NSE), and Accuracy. The results of these performance indicators are compared and analyzed among each DEM. The accuracy assessment is evaluated in two different aspects that are, concerning elevations and slope value. The result shows that ALOS is most accurate concerning both elevation and slope. To extract the elevation data of the terrain ALOS is most preferable, and similarly ALOS gives a comparatively precise slope value.

Keywords—Accuracy assessment, Digital Elevation Model, Real-Time Kinematic (RTK)

1. Introduction

A Digital Elevation Model (DEM) is a specialized database that represents the relief of a surface between the point of known elevation. In Bhutan, generating slope maps using DEMs is not widely used, National Land Commission Secretariat (NLCS) and only other few agencies are using DEMs for analyzing topographical study [1]. DEMs are important in providing valuable geological information that can be used as a guide in defining the geology of a given area. To represent exact information about the Earth's surface, the vertical accuracy of DEMs must be higher so that it can be used to determine the attributes of terrains [2], such as elevation at any point, slope, and aspect. Until now in Bhutan, the research

on the vertical accuracy assessment of DEMs is not carried out and accuracy of these three DEMs has not evaluated.

Digital Elevation Models (DEMs) are recognized as a core spatial dataset required for many environmental applications. However, the availability of comprehensive DEMs for water resources studies is rather limited and limitations of current, free or open-access DEMs are well-known [3]. Freely available and global scale DEMs, such as that from the Shuttle Radar Topography Mission (SRTM) or the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) mission exhibit large vertical errors which are exacerbated over complex topography and they cannot resolve microtopographic variations in relatively flat terrain. In a study, [4] argued that inundated areas from a flood simulation, albeit a

simplistic case in their study, vary significantly across different DEM data sources. In another study dedicated to hydrologic applications, [5] evaluated the vertical accuracy of open source DEMs (ASTER and SRTM) and concluded that slope and drainage network delineation are largely violated compared to their reference DEM [6].

Spatial resolution, absolute error in the vertical, and accuracy in relative gradient (slope) are all important attributes of a DEM, and the requirements of those need to be properly established. Whilst views on the impact of spatial resolution may be more varied, depending on the complexity of the process simulated or indeed the DEM source [5] absolute and relative accuracy in the vertical is crucial, and even small vertical errors can have significant impacts on the application accuracy, especially at the local scale. Thus, the accuracy of Digital Elevation Models (DEMs) is important to figure out for its many environmental applications.

This research presents the result through statistical analysis to compare the accuracy of DEMs dataset, Shuttle Radar Topography Mission (SRTM), Advance Spaces Borne Thermal Emission and Reflection Radiometer (ASTER), and Advanced Land Observing Satellite (ALOS) which is freely available global DEMs. For accuracy assessment, total elevations data of 400 ground controls points (GCPs) randomly distributed within the Jigme Namgyel Engineering College boundary were used. They were measured using a real-time kinematic assuring ± 1 and ± 2 cm accuracies, respectively, for planimetry and altimetry.

This project aims to do a comparative study of vertical accuracies among three DEM datasets over Ground Control Points (GCPs) collected by Real-Time Kinematic (RTK) within Jigme Namgyel Engineering College to analyze the accuracy of DEMs to select the best among three

This project involves the extraction of three DEMs (SRTM, ALOS, ASTER) of 30m resolution from U.S. Geological Survey (USGS) Earth Explores and generate reference DEM over the JNEC campus. The reference DEM is generated through GIS using existing GCPs and spot heights collected through Real-Time Kinematics (RTK). For the vertical accuracy assessment of DEMs, 20 Ground Control Points (permanent GCPs) and 380 elevation points within the Jigme Namgyel Engineering College boundary were used. The elevation points collected are randomly distributed, covering the maximum area of the JNEC campus.

1.1. Study Area

Jigme Namgyel Engineering College (JNEC) is located at the west end of Dewathang town, 18 kilometers from Samdrup Jongkhar. JNEC lies between the coordinates 26°51′06′′N to 26°51′54′′ and 91°26′48′′E to 91°26′06′′E with an elevation of 800m (2,600ft).

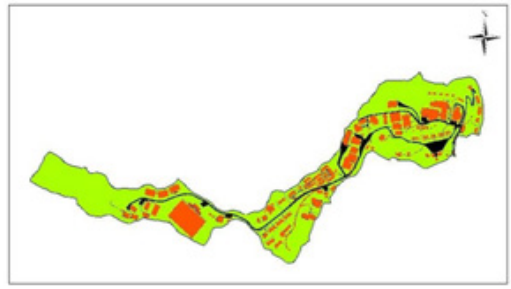

Figure 1: Study Area

2. Data and Methods

2.1. Data

2.2.1.Advanced Land Observing Satellite (ALOS) Data

The ALOS was released in 2015 by the Japan Aerospace Exploration Agency (JAXA) The ALOS is a sample of the 5-meter mesh version of the World 3D Topographic Data, which is considered to be the most precise global-scale elevation data at this time [7]. ALOS was produced using the traditional optical stereo matching techniques applied to images acquired by the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) sensor onboard the Advanced Land Observing Satellite (ALOS) [8]. The accuracy of the 5-meter mesh version of this DEM has been reported in a few studies. found [9] that the ALOS has height accuracies better than 5-meter in four test sites with varying terrain features while [10] found the same DEM version to have a Root Mean Square Error (RMSE) of almost 4-meter based on comparisons with various data sets including airborne LiDAR Digital Surface Model (DSM) and Ground Control Points (GCPs).

Table 1: List of DEMs used for comparisons and geomorphic analyses

Data	SRTM	ASTER	ALOS
Resolution (m)	30 M	30 M	30 M
Coverage	60°N-56°S	83°N-83°S	82°N-82°S
Source	Public, https://lta.cr.usgs.gov/ SRTM1Arc	Public, https://asterweb.jpl.nasa.gov/	Public (30m), http://www.eorc.jaxa.jp/ALOS/en/aw3d30/ Commercial (5m), http://aw3d.jp/en/
Notes	Launched in February 2000, released 2014, previously only US coverage.	Released 2011, update of ASTER released 2009. Generated by automated processing and stacking of ASTER stereo pairs by NASA and METIa	5m DEM released 2015 as highest-resolution commercial global DEM, with downsampled 30m research version released 2016.
Country	US	Japan	US
Application	Periglacial geomorphology Vegetation surveys	Geomorphic Description and Analysis Relief Identification and Profiles Creations	Disaster Mitigation Monitoring global environment change

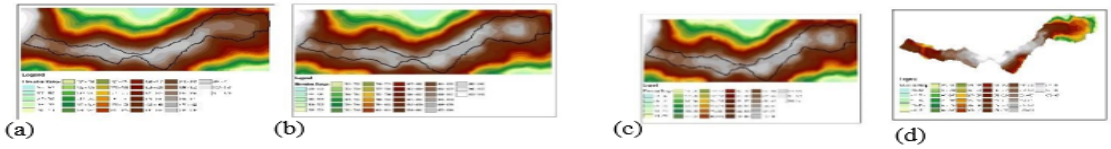

Figure 2. (a)SRTM (b)ALOS (c)ASTER (d)RTK

2.1.2. Shuttle Radar Topography Mission (SRTM) Data

The Shuttle Radar Topography Mission (SRTM), flown on Space Shuttle Endeavour in 2000 and was a joint project of the National Aeronautics and Space Administration (NASA), [11] the National Geospatial-Intelligence Agency (NGA), and the German and Italian Space Agencies [12]. The SRTM 30-meter objective was to acquire a Digital Elevation Model of all land between latitudes of 60ºN and 56ºS, about 80% of the Earth's land surface The SRTM 30-meter is an improvement to the lower solution SRTM topographic data having 90-meter (3 arc-seconds). The new data, released in September 2014, increase the detail to 30- meter (1 arc-second), revealing the full resolution of the world's landforms as originally measured by SRTM in the year 2000 [13]. According to its mission objectives, SRTM DEMs are expected to have linear vertical absolute height error of less than 16m, linear vertical relative height error of less than 10 m, circular absolute geolocation error of less than 20 m, and circular relative geolocation error of less than 15 m [14]. SRTM DEM is mainly controlled by factors including measuring precision, timing error, multi-path coefficient, phase measuring error, and radar thermal noise. The horizontal and vertical accuracy specifications at 90% circular error [15]. The DEM extracted from SRTM data can be used in conjunction with controlled imagery sources to provide better visualization of the terrain. DEMs have a key role in improving accuracy in soil and agricultural characterization [16].

2.1.3. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Data

ASTER was considered to be the highest resolution DEM among the free accessible global DEMs during its release in 2011 [17]. The ASTER GDEM v2 contains significant improvements of Version 1 (released in 2009) in terms of spatial coverage [refined horizontal resolution, [18] increased horizontal and vertical accuracy, water masking, and inclusion of new ASTER data to supplement the voids and artifacts [19]. Although vastly improved, some artifacts still exist in the form of abrupt rise (humps/bumps) and fall (pits) which can produce large elevation errors on the local scale [20]. Compared to ALOS and SRTM-30m,

studies assessing the quality and vertical accuracy of ASTER GDEM v2 are higher[19].

2.1.3. Production of independent Checkpoints (ground truth) using RTK

If only 28 checkpoints are considered, as recommended by USGS, the confidence level value is around 85%. Henceforth, to reach a 95% confidence level, approximately two hundred (200) GCPs must be considered. To guarantee the vertical error assessment constancy, 200 points will be used for calibration and the other 200 points will be used for validation in this research. Total of 400 ground-truthing points over the JNEC boundary including 20 existing GCPs.

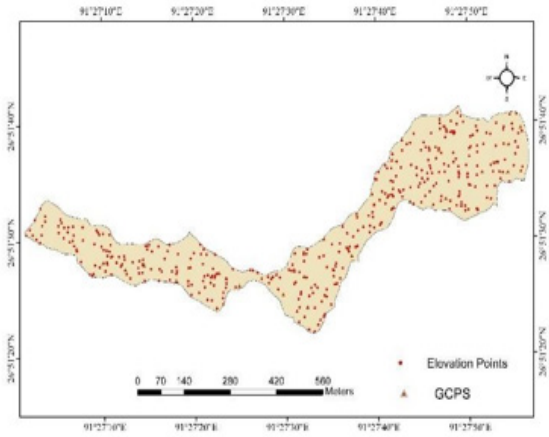

Figure 3 RTK Elevation points

2.2. Method

2.2.1. Correlation analysis Correlation of coefficient (r)

The correlation coefficient, r is a statistical measure of the strength of the relationship between the relative movements of two variables. The values range between -1.0 and 1.0. A calculated number is greater than 1.0 or less than -1.0 means that there was an error in the correlation measurement. A correlation of -1.0 shows a perfect negative correlation, while a correlation of 1.0 shows a perfect positive correlation. A correlation of 0.0 shows no linear relationship between the movement of the two variables.

From the total of 400 ground-truthing points, 200 points were used for calibration while another 200 was used for validation.

2.2.2. Error Assessment Root Mean Square Error (RMSE)

That also measures the average magnitude of error, which is the square root of the average of squared differences between an actual observation (Zi) and prediction (Zi) at N stations. RMSE is the most frequently used characteristics determining the degree of accuracy or the measure of conformity between a set of estimates and actual values. It expresses the dispersion of frequency distribution of variances between original(actual) height data and DEM data.

$$RMSE = \sqrt{\frac{\sum(Z_i - Z_j)}{N}} \qquad (1)$$

Based on Standard Deviation (SD)

Standard deviation (SD) is a statistical measure of the dispersion of a dataset relative to its mean. It is calculated as the square root of variance by determining the variation between each data point (Zi) relative to the mean (Z-bar), and N is the number of observations in the sample. It is a measure of how spread out numbers are. A low standard deviation indicates that the data points tend to be close to the mean (also called the expected value) of the set, while a high standard deviation indicates that the data points are spread out over a wide range of values.

$$SD = \sqrt{\frac{\sum_{i=1}^{N}(Z_i - Z_{bar})^2}{N-1}} \qquad (2)$$

Mean Absolute Error (MAE)

In statistics, mean absolute error (MAE) is a measure of errors between paired observations expressing the same phenomenon. Examples of Y versus X include comparisons of predicted versus observed, subsequent time versus initial time, and one technique of measurement versus an alternative technique of measurement.

MAE is calculated as:

$$\frac{\sum_i^n (y_i - x_i^0)}{n} = \frac{\sum_{i=1}^n e_i}{n} \qquad (3)$$

Note that alternative formulations may include relative frequencies as weight factors. The mean absolute error uses the same scale as the data being measured. This is known as a scale-dependent accuracy measure and therefore cannot be used to make comparisons between series using different scales. The mean absolute error is a common measure of forecast error in time series analysis, sometimes used in confusion with the more standard definition of mean absolute deviation. The same confusion exists more generally.

2.2.3. Accuracy assessment Accuracy

Confidence Level, in statistics, refers to the probability that a population parameter will fall between two set values for a certain proportion of times. Confidence intervals measure the degree of uncertainty or certainty in a sampling method. A confidence interval can take any number of probabilities, with the most common being a 95% or 99% confidence level.

Confidence intervals provide more information than point estimates. By establishing a 95% confidence interval using the sample's mean and standard deviation, and assuming a normal distribution as represented by the bell curve, the researchers arrive at an upper and lower bound that contains the true mean 95% of the time. Lowest the value of accuracy obtained using RSME equation interpret better performance ("math is fun"2020).

3. RESULTS

3.1. Correlation analysis

Calibration It has been demonstrated that DEM accuracy can vary to a certain degree with different interpolation algorithms and interpolation parameters. Several interpolation methods existents in ArcGIS and other mapping software, and the best and appropriate DEM interpolation must reproduce as close as possible the terrain shape (Hamied, 2016). Consequently, the approach of the calibration was considered in this study to generate the respective elevation and slope value from DEMs.

From the correlation graph in Fig 4a, we observed that among three DEMs, the ALOS elevations correlate strongly with RTK elevations showing the highest coefficient of determination (R^2) of 0.9513.

According to NDEP (National Digital Elevation Guidelines) and FEMA guideline, a measure of accuracy can be computed as follows:

$$\text{Accuracy} = \text{RSME} * 1.96 \quad (4)$$

$$\text{Accuracy} = \text{RSME} * 2.58 \quad (5)$$

3.2. Nash-Sutcliffe Efficiency (NSE)

Nash-Sutcliffe Efficiency (NSE) is a normalized statistic that determines the relative magnitude of the residual variance compared to the measured data variance can range from -∞ to 1. An efficiency of 1 (NSE = 1) corresponds to a perfect match of modeled discharge to the observed data. An efficiency of 0 (NSE = 0) indicates that the model predictions are as accurate as of the mean of the observed data, whereas an efficiency less than zero (NSE < 0) occurs when the observed mean is a better predictor than the model or, in other words, when the residual variance (described by the numerator in the expression above), is larger than the data variance (described by the denominator).

$$NSE = 1 - \frac{\sum_{i=1}^{n}\left(Y_i^{obs} - Y_i^{sim}\right)^2}{\sum_{i=1}^{n}\left(Y_i^{obs} - Y_i^{mean}\right)^2} \quad (6)$$

Where, Y_i^obs is the observed data, Y_i^sim is simulated value, Y_i^mean is the mean observed data, and 'n' is the total number of observations.

The second highest 'R^2' is shown by SRTM with 0.8931 followed by ASTER which has the least 'R^2' of 0.6656. These correlations indicate that ALOS has a strong linear relationship with RTK elevations. The ALOS and SRTM also prove a strong correlation because all the points are equally distributed above and below the line of best fit whereas, ASTER shows that the majority of cloud points are below the line of best fit confirming that it's underestimated elevations significantly.

From Figure 4b, we also observed that for the slope, SRTM shows the highest coefficient of determination (R2) of 0.2816 followed by ALOS and ASTER. which means compared to ALOS and ASTER, it shows better linearity with RTK elevations. ALOS shows 'R^2', 0.196, and ASTER has the least 'R^2' of 0.1827 almost equal to ASTER.

In this method of validation, the three different DEMs were validated with 200 elevation points

collected using RTK randomly distributed over the JNEC.

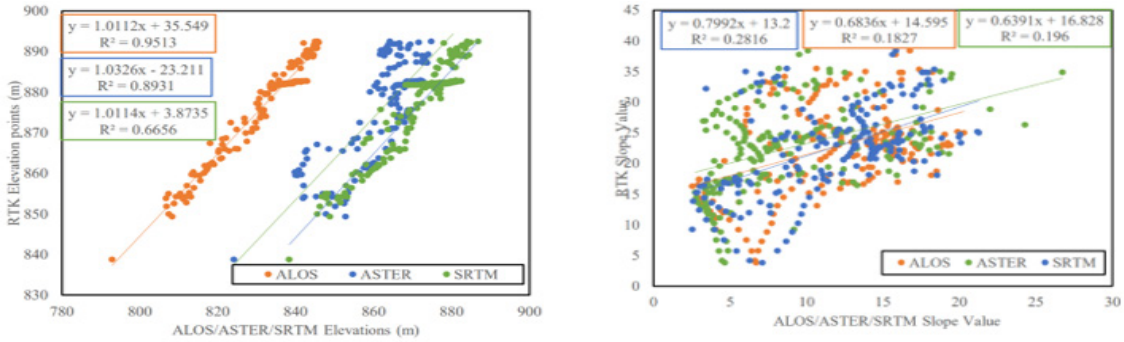

Figure 4: Calibration Plot for (a) elevations (b) slope

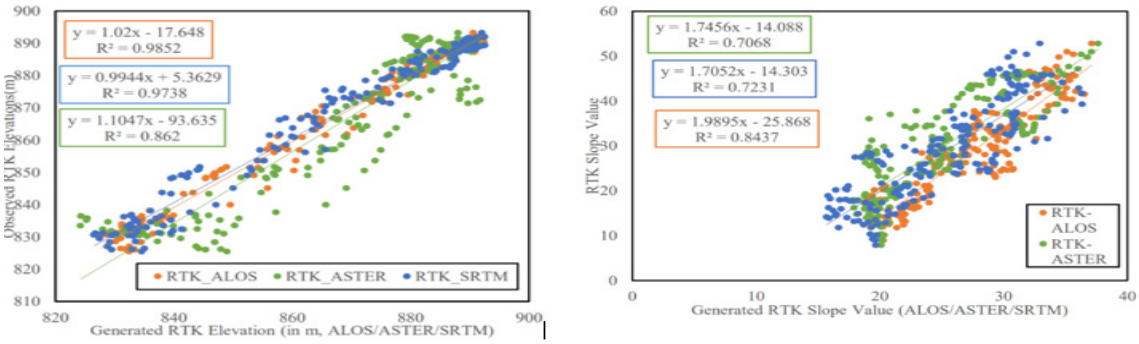

Figure 5. Validation Plot for (a) elevation points (b) slope

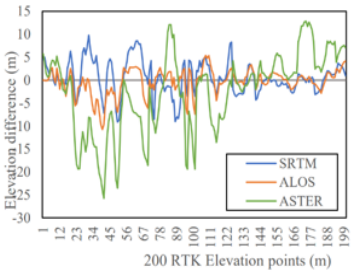

Figure 6: Absolute elevation difference between RTK and different DEMs

3.2 Absolute Elevation Difference w.r.t RT

Table 2 summarizes the statistics of absolutes elevation differences (Δh) between the 200 GCPs measured by RTK and their corresponding homologous elevation points in each considered DEM. These elevation differences are also illustrated by the scatter plot in Figure 6. In Figure 6, the "X" axis of this scatter plot at the coordinate (0, 0), named also zero error axis, is a hypothetical "ideal" line which

around it theoretically must gravitate the cloud points showing the perfect concordance between the ground truth (RTK) and they are homologous. More the points are closer to this hypothetical line (zero elevation difference) more the accuracy is better and vice-versa. However, most likely this assumption is not always validated because the elevation estimation accuracy is often influenced by the nature of the land use classes, nature of targets, various terrain slopes, several terrain morphologies, and several error sources.

The ALOS elevation points are well distributed around the "X" axis showing the minimum and maximum difference variations between -10.758m and 5.383m respectively with a minimum SD of ± 2.803. Although the SRTM shows satisfactory SD (± 3.676), elevation points are very scattered concerning the hypothetical zero error line between -9.133m and 9.798m; which means a relatively significant error compared to reference DEM. While the ASTER altitude difference diverges vastly between -25.748m and 12.840m with the lowest SD of ±8.672.

3.3. Accuracy Ranking of DEMS

DEMs have their characteristics and performance levels over the different land features. The reliability

Table 2. Absolute elevation difference

Statistics	ALOS	ASTER	SRTM
Minimum	-10.758	-25.748	-9.133
Maximum	5.383	12.840	9.798
Mean	-0.322	-2.601	0.512
Standard deviation	± 2.803	± 8.672	± 3.676

Table 3: Accuracy and error assessment for elevation

Performance indicators	RTK	SRTM	ALOS	ASTER
Correlation (r)	1	0.968	0.992	0.928
Correlation of determination (*r^2*)	1	0.973	0.985	0.862
RMSE	0	0.715	0.567	1.612
MAE	0	0.512	0.322	2.601
NSE	0	0.973	0.985	0.841
Accuracy (5% significance level)	0	1.402	1.111	3.16
Accuracy (1% significance level)	0	1.845	1.462	4.168

Table 4 Score Board of DEM Datasets for elevations.

DEM	Performance indicators							Sum	Rank
	Correlation (r)	Coeff. of determination (r^2)	RMSE	MAE	NSE	5% significance level	1% significance level		
ALOS	3	3	3	3	3	3	3	21	1
ASTER	1	1	1	1	1	1	1	7	3
SRTM	2	2	2	2	2	2	2	14	2

of DEMs depends on their purpose of usage and its application, resulting in varying in its errors. Therefore, finding a higher accuracy of DEMs can approach by assigning weight based on DEM's performance and effectiveness. For the selection of best among three different DEMs datasets, relative weight is assigned to respective preference in each assessment method, that is performance indicator. Higher weights are assigned to the most accurate DEMs having the least errors. Among three DEMs, a Weight value of 3 is assigned to the most accurate DEM, weight value 2 was assigned second-most accurate DEM, and Weight of 1 was assigned to less accurate concerning each performance indicator. A higher value of weight indicates higher accuracy of DEM.

From the table 4, it shows that ALOS gives accurate result with each performance indicators and thus it is in rank 1 which means an ALOS is most accurate followed by SRTM and the ASTER in the lowest rank. Therefore, ALOS is suitable for collecting elevation points over a terrain if needed for many applications of elevation data. It has a minimum error and the elevations generated from ALOS are almost equivalent to the RTK elevations which are very accurate.

ALOS shows the highest performance followed by SRTM and ASTER. Regarding RTK slope value, ALOS have the lowest error with the highest accuracy. The SRTM is in rank 2 followed by ASTER in rank 3 with the highest error and least accuracy. a followed by ASTER with the highest RMSE with the lowest accuracy. The result concludes that, for generating slope maps and comparing the accuracy of slope elevations, ALOS is preferable over SRTM and ASTER.

4. Conclusion

Digital Elevation Models (DEM), which can occur in the form of Digital Surface Models (DSM) or Digital Terrain Models (DTM) are widely used as important geospatial information sources for various remote sensing applications, including the precise orthorectification of high-resolution satellite images. Digital Elevation Models (DEMs) are recognized as a core spatial dataset required for many environmental applications. The three different DEMs (ALOS, ASTER, and SRTM) of 30m resolutions were extracted from USGS Earth Explorer. The comparison of vertical accuracy of these DEMs was done concerning the reference DEM generated from the points collected using the RTK. Six different performance indicators (correlation, correlation of determination, RSME, MAE, NSE, and Accuracy) were used to rank the performance and accuracy of each DEM concerning elevations and slope data. From the elevation data ALOS illustrates strong correlation (r=0.992) with RTK elevations with lowest RMSE (0.567) and MAE (0.322). The SRTM has a strong correlation (r=0.973) but it has more RSME and MAE values of 0.715 and 3.556 respectively showing more error associated with it. The ASTER has high RMSE and MAE errors of 1.612 and 2.601 respectively showing the least accuracy and efficiency. Hence, for extracting elevations of a terrain, SRTM is preferable over ALOS and ASTER.

Similarly, from the slope data, it was found out that ALOS performs best over ASTER and SRTM displaying the lowest RSME (1.190), MAE (1.386), and highest accuracy with 2.332 of 95% CL. In addition, ALSO DEM is most efficient with an NSE of 0.948 compared to the other two DEMs which conveys that the DEM slope values match almost perfectly with observed data (RTK slope values). Hence for comparison of slope data and generating slope map of the terrain, ALOS is preferable over ASTER and SRTM because it has a minimum error and highest accuracy. Finally, in this study, only 400 elevation points as reference data are collected using RTK over the Jigme Namgyel Engineering College covering an area of 56.283 acres. The RTK maintains the errors in the vertical coordinates of the estimated position from 27 mm to 13 mm for the reference network with 70 km between the reference station. Some errors are created in the collection of elevation points and the processing of data. However, an accurate comparative study of DEMs can be generated by extending the area, covering different land features. Also considering the different nature of the terrain and removing the errors associated with DEMs can help to find a reasonable answer.

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REFERENCE

S[1] L, S. I., Rachmat, M., S, D. H., Agus, S., Rahmat, A., & Shadiq, A. (2019). “Study of Digital Elevation Model (DEM) Extraction using Stereo Radargrammetry TerraSAR- X in Madiun Area –

Elevation Accuracy Improvement" pp.3–6, 2019".

[2] Lin, L. S. (n.d.). "Application of GPS, RTK and Total Station system on dynamic monitoring land use" 116, Taiwan, Republic of China. 3, 1– 6.".

[3] Yang, L "SRTM DEM and its application advances". . "International Journal of Remote 2019

[4] Santillan, J.R, & Santillan, M. "Vertical accuracy assessment of 30-m resolution ALOs, SRTM, ASTER global DEMs over northeastern Mindanao, Philipppines". The international Archives of the Photogrammetry, Remotesensing and Spatial Information sciences. ISPR Congress. Vol XL_ B-4, pp.149-156, 2016.

[5] "Farah, A., & Abdallah, A. T. "Accuracy Assessment of Digital Elevation Models Using GPS",. https://doi.org/10.2478/v10018-009-0014-7, vol.42, no.3, pp.151-161, 2009

[6] Chang, H.-C., L. Ge, and C. Rizos, Assessment of digital elevation models using RTK GPS. Journal of Geospatial Engineering, 2004. Vol 6, no. 1 p. 13.

[7] Meyer D. "ASTER GDEM Version 2. Summary of validation results. p: 27. 2011".

[8] "Takaku, J.; Tadano, T.; Tsutsui, K.; Ichikawa, M. Validation of 'AW3D' global DSM generated from ALOS PRISM. ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci. 2016, 3, 25–31.

[9] "Tadano, T.; Nagai, H.; Ishida, H.; Oda, F.; Naito, S.; Minakawa, K.; Iwamoto, H. Generation of the 30 m-mesh global digital surface model by ALOS PRISM. Int. Arch. Photogramm. RemoteSens. Spat. Inf. Sci. 2016, XLI-B4, 157–162.

[10] "NASA (2005) Shuttle Radar Topography Mission.".

[11] Alganci, U. "Accuracy Assessment of Different Digital Surface Models." Pp. 1–16. https://doi.org/10.3390/ijgi7030114" 2011.

[12] Balasubramanian, A. "Digital elevation model (dem) in GIS." https://doi.org/10.13140/RG.2.2.23976.47369, 2017

[13] Mukul, M., Srivastava, V. "Analysis of the accuracy of Shuttle Radar Topography Mission (SRTM) height models using International Global Navigation Satellite System Service (IGS)Network". J. Earth Syst. Sci. 2015, 124, 1343–1357.".

[14] Adeola, F. O., Jolade, O., & Adeyemi, O. "An Assessment of Digital Elevation Model for Geospatial Studies: A Case Study of Alawa Town, Niger State, Nigeria". December" 2017.

[15] Shimada, M. "Advanced Land Observing Satellite (ALOS) and Monitoring Global Environmental Change". https://doi.org/10.1109/JPROC.2009.2033724, 2010 ".

[16] USGS (2015) "Global data explorer for ASTER GDEM.".

[17] Yastikli, N. "Automatic digital elevation model generation, problems and restrictions in urban areas". 2015

[18] Aher, S., Bairagi, S. "Applications of Advanced Spaceborne Thermal Emission and Reflection Radiometer's (ASTER) DEM in spatial planning" . Online International Interdisciplinary Research Journal Vol 2, no. 6, 2012

[19] Smith B, Sandwell D "Accuracy and resolution of shuttle radar topography mission data." Geophysics Research Letter 30: 1467. 2003".

Design of Cold Storage in JNEC Mess

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ABSTRACT - The average temperature of Samdrup Jongkhar does not qualify for the average temperature specified to store fruits and vegetables which compels for the frequent market scheduling. The location of institute from the market is 18km which is not a fine distant to carry out frequent shopping. Storing products for longer duration without cooling facilities is not possible too. Therefore, the design of the cold storage system intends to improve the after-harvest life of vegetables and fruits, reduce the frequent shopping and design cheap and simple cold storage unit. This will help improve the hygiene, nutrition and provide variety of different fruits and vegetables to the students.

The main working components of the system are circulation fan and the sand in the cavity of the walls. The system works on evaporative cooling method where the sand in the cavity of walls is kept wet by pouring water into it from the tank through pipes. As the ambient temperature becomes high, the water from the wet sand in the cavity evaporates. As it evaporates, it absorbs certain amounts of heat from the walls in contact with the sand making the internal room relatively cooler in which the vegetables can be kept.

1. INTRODUCTION

Cold storage is the process storing products below the ambient temperature of the area. In many places, cold storage is necessary to stop food and drinks from being immediately ruined by rising heat or temperature. Cold storage offers consistency of storage temperature, the ability to transport goods over long distances, the ability to enjoy produce out of season and the ability to store delicate pharmaceuticals and chemicals at their ideal storage temperature.

Evaporative cooling is a physical phenomenon in which the evaporation of liquid into surrounding air cools a body in contact with it. It cools down a body with using its heat contain so as to convert liquid into vapor state. Therefore, evaporative cooling works by utilizing the natural process of water evaporation, along with an air moving system, to create an effective cooling environment.

There are mainly two basic types of evaporative cooling systems are present namely direct and indirect evaporative cooling systems. In direct evaporative cooling system, the air passes straight across the humidifier into the cooling chamber, while in an indirect evaporative cooling system the air is first pre-cooled with heat exchangers before passing it through the cooling pad or vice versa depending on the purpose of cooling. Passive evaporative systems are mostly applicable in the windy environment with large amount of air moving around and low-pressure head. This is the oldest method of evaporative cooling and sometimes referred to as zero energy cooling as it does not consume any commercial energy.

2. LITERATURE REVIEW

Datta et al (1987) have experimentally studied an 8.5 ton indirect-direct evaporative cooling system and reported that such a system provides a relief cooling rather than comfort cooling. The room could be maintained at 4-5 ºC above the inlet wet bulb temperature using such a cooler. A facility of using indirect-direct evaporative cooling for residential use in arid regions of Israel is attempted by Navon and Arkin (1994). Such a system is shown to provide higher level of thermal comfort where external humidity is around 80 %.

El-Dessouky et al (2000) have developed a membrane air dryer and coupled with conventional direct / indirect evaporative cooler. As the membrane drier, removes the moisture from the incoming air, the air can be cooled to lower temperature by

the subsequent evaporative cooler. Using such a system, reasonable cooling has been obtained. When such system is combined with Mechanical Vapour Compression system to achieve to perfect thermal conditions, about 50 % savings in electricity are obtained.

Jain (2007) has developed and tested a two-stage evaporative cooler. Such a cooler could provide necessary comfort even though outside humidity is higher. The two-stage cooler is found to provide 20 % better cooling when compared to single stage cooler. A novel dew point evaporative cooling system for sensible cooling of ventilation air has been developed by Riangvilaikul and Kumar (2009) and tested experimentally. Wet bulb effectiveness of 92-114 % and the dew point effectiveness 58-84 % are reported. Heidarinejad et al (2010) have tested a ground assisted hybrid evaporative cooling system in Tehran. The ground coupled circuit provides necessary pre-cooling effects. Simulation studies have shown that such a hybrid system can provide cooling effectiveness of 100-110 %.

3. PROBLEM STATEMENT

The warmest and coldest months, July and January, average temperature in Samdrup Jongkhar ranges 28°C/83.1°F to 16.5°C/61.7°F respectively according to the climate summary of Samdrup Jongkhar. The average temperature specified to store fruits and vegetables is between 10°C to 14°C, due to the higher average temperature of Samdrup Jongkhar it makes necessary to install good cold storage systems. Along with it the market distance is 18km from the institute which imposes the problem of time as well as the labor consumption as the shopping is scheduled twice a week. With the development of a good cold storage device, we can reduce the shopping interval which inevitably reduces the labor force. This helps the concern staff, councilors, student's representatives and students involved in mess related works.

4. WORKING MECHANISM

4.1. Physical principle

Evaporative coolers lower the temperature of air using the principle of evaporative cooling. Evaporative cooling is the conversion of liquid water into vapor using the thermal energy in the air, resulting in a lower air temperature. The energy needed to evaporate the water is taken from the air in the form of sensible heat, which affects the temperature of the air, and converted into latent heat, the energy present in the water vapor component of the air. This conversion of sensible heat to latent heat is known as an isenthalpic process because it occurs at a constant enthalpy value. Evaporative cooling therefore causes a drop in the temperature of air proportional to the sensible heat drop and an increase in humidity proportional to the latent heat gain.

4.2. Construction

This cold storage is an average sized house with the internal volume of 15.625 cubic meter. The house has two walls with the cavity between them to be filled by the sand. The roof the house bears the tank with the volume of 1 cubic meter. The tank is filled by the water used to soak the sand in the wall cavity.

5. DESIGN ANALYSIS

a) Design of the cold storage

Internal dimension of the cold storage

- Length = 2.5m
- Breadth = 2.5m
- Height = 2.5m

Therefore, the internal volume of the cold storage is;

$$V = l \times b \times h = 2.5 \times 2.5 \times 2.5 = 15.625m^3$$

- For the calculation of the cavity volume in the walls Length = 2.5 m; Breadth = 0.1m; Height = 2.5m Therefore, the volume of the cavity is;

$$V = 2.5 \times 2.5 \times 0.1 = 0.625m^3$$

External dimension of the cold storage

Length = 3.08m; Breadth = 3.08m; Height = 2.5m, therefore, the external volume of the cold storage is;

$$V = 3.08 \times 3.08 \times 2.5 = 23.716m^3$$

b) Cooling load calculation

The cooling load is the amount of heat energy that

would need to be removed from a space (cooling) to maintain the temperature in an acceptable range.

1. Transmission load through walls, roof and floor.

$$Q = \frac{U \times A \times (T_o - T_i) \times 24}{1000}$$

Where, $Q = heat\ load$
$U =$ heat transfer coefficient
$A = area$
$To = outside\ temperature$
$Ti = inside\ temperature$

We have,
$U = 0.6W/mK$
$A = 37.5m^3$
$T_o = 28°C$
$T_i = 10°C$

Therefore,
$$Q = \frac{0.6 \times 37.5 \times (28-10) \times 24}{1000}$$
$= 9.72$ kWh/day

2. Product load – Product exchange

$$Q = \frac{m \times C_{Pmixture} \times (Tenter - Tstore)}{3600}$$

Where, $Q = heat\ load$

$m = total\ product\ mass$

$C_{p_{mixture}} = avg\ specific\ heat\ capacity\ of\ mixed\ produc$

$Tenter = the\ entering\ temperture\ of\ the\ products$

$Tstore = the\ temperature\ within\ the\ store$

We have,
$m = 800kg$
$C_{p_{mixture}} = 3.79kJ/kg°C$
$Tenter = 28°C$
$Tstore = 10°C$

Therefore,

$$Q = \frac{800 \times 3.79 \times (28-10)}{3600}$$
$= 15.16$kWh/day

3. Product load-Product respiration

$$Q = \frac{m \times Rep}{3600}$$

Where, $Rep =$ *the respiration heat of the product*

We have,
$m = 800kg$
$Rep = 3.9kJ/kg$

Therefore,
$$Q = \frac{800 \times 3.9}{3600}$$
$= 0.87kWh/day$

4. Internal heat load – Lighting and fan

$$Q = \frac{Number\ of\ appliance \times Time \times Wattage}{1000}$$

We have, $Number\ of\ appliance = 2$
$Time = 23hours$
$Wattage = 59W$
Therefore,
$$Q = \frac{2 \times 23 \times 59}{1000}$$
$= 2.714kWh/day$

5. Total cooling load

We have,
Transmission load = 9.72kWh/day
Product load = 16.03 kWh/day
Internal load = 2.714kWh/day

Therefore,
Total load = 28.464 kWh/day

6. COST ANALYSIS

a) Running cost
- ✓ Fan:
  Power rating = 50 watt
  Running hour = 20 hours a day
  Rate = Nu. 3.42 / unit (1 unit = 1kWh)
  $\frac{50}{1000} \times 20 = 1\ kWh$

$1\ kWh \times Nu.3.42 = Nu.3.42/\ day$

- ✓ Light:
  Power rating = 9 watt
  Running hours = 3 hours a day
  Rate = Nu. 3.42 / unit
  $\frac{9}{1000} \times 2 = 0.018\ kWh$
  $0.018\ kWh \times Nu.3.42 = Nu.0.06156/\ day$

Total cost = $Nu.3.42 + Nu.0.06156 = Nu.3.4815/\ day$

Total cost in a month = $Nu.3.4815 \times 30 = Nu.104.445/\ month$

Total cost in a year = $Nu.3.4815 \times 365$ = Nu. 1270.7475/ year

6. CONCLUSION

There has been the usage and discovery of cold storage systems since a long time and as it can be seen that cold storage system has evolved very with time. In the olden eras, people developed cold storages with just the simple and materials which were available around them in their time, and it included materials like rocks, water, stick, bamboos in huts and etc. As times changed, many things were discovered, invented and implemented on the existing cold storage systems, it included air conditioners, humidifiers, fans, pumps and so on. Cold storages systems kept on improving its quality, working ranges and other aspects as well.

As the cold storage systems kept on improving and implementing new ideas, its cost and complexity also increased. It became difficult for the farmers and common people to afford using the modern cold storages. Therefore, we have designed our cold storage system, a zero-energy cool storage, in such a way that we have reduced the complexity, number of components relatively reducing the cost of our project. Unlike other cold storage systems, our system does not emit and harmful CFCl (chloro-fluoro-carbon) gases to the environment making it environment friendly. The cold storage system we have designed is a simple passive evaporative cooling system.

REFERENCE

[1] ASHRAE handbook, 1981 Fundamentals, New York: American Society of Heatng, Refrigeration and Air-Condition Engineers, 1981.

[2] E.-D. Hisham T. and . M. E. Hisham, "Evaporation Rates from Fresh and Saline Water in Moving Air," ndustrial & Engineering Chemistry Research, vol. 41, no. 3, pp. 642-650, 2002.

[3] I. V.-R. J. M.-R. A. O.-S. E. B.-L. Melitón Estrada-Jaramillo, "Empirical Model to Calculate the Thermodynamic Wet-Bulb Temperature of Moist Ai," Engineering, Vol.6 No.9, August 5, 2014.

[4] A. S. N. M. I. A. Hassan, "The numerical modelling of falling film thickness flow on horizontal tubes," 21 April

2017. [Online]. Available: https://aip.scitation.org/doi/abs/10.1063/1.4981161. [Accessed 2020].

[5] O. P. O. P. O. Olaifa, "Comparative Evaluation of Pot-in-Pot and Metal in Pot Evaporative Cooling Systems," International Journal of Trend in Scientific Research and Development (IJTSRD), vol. 3, no. 3, 2019.

[6] P. U. L. F. T. A. S. M. B. Bogdan Porumb, "A review of indirect evaporative cooling technology," Sustainable Solutions for Energy and Environment, p. 461 – 471 , 2015.

[7] E. S. Camargo, "Experimental performance of a direct evaporative cooler operating during summer," International Journal of Refrigeration-revue Internationale Du Froid. Oxford: Elsevier B.V., vol. 28, no. 7, pp. 1124-1132, 2005.

[8] D. Jain, "Development and testing of two-stage evaporative cooler," Building and Environment , vol. 7, no. 42, pp. 2549-2554, 2007.

[9] S. A. H. Waleed A. Abdel-Fadeel, "Calculations in the outlet air of direct evaporative coolers," Journal of Engineering Sciences, Assiut University, vol. 40, no. 5, pp. 1351-1358 , 2012.

[10] B. U. S. P. C. O. J.T. Liberty, "Principles and Application of Evaporative Cooling Systems for Fruits and Vegetables Preservations," International Journal of Current Engineering and Technology , vol. 3, no. 3, pp.1000-1006, 2013.

[11] M. R, Fundamentals of HVAC Systems, Elsevier, San Diego: P. Eng. Engineering Change Inc, 2006.

IoT Based Garbage Monitoring System

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Abstract — Proper waste management is still a major problem in Bhutan. Increase in the population and the essence of comfortable living gave a tremendous growth in the urban areas resulting in the generation of huge amount of solid wastes. Improper management has led to overflowing of waste at public places which degrades the environmental beauty, invites scavengers, pollutes air along with spreading of various health related illnesses. The standard method of manually monitoring the waste in the garbage bin is a complex, cumbersome process and utilizes more of human effort and time. To improve waste management, one way is to develop a proper garbage monitoring system to control overflowing of waste and to efficiently use time. This project 'IoT based Garbage Monitoring System' makes uses of internet of things technology to monitored the level of garbage by providing real time information to the concerned person. The system is divided into three levels where it is indicated by green, orange and red for ground, normal and full level respectively. The system makes use of Arduino as a microcontroller, ultrasonic sensor for level detection and Wi-Fi module to send the data to cloud. A user can access the status of the dust bin from either webpage, mail or from the ThingSpeak viewer app. Thus, based on the statues received necessary actions can be taken. This optimizes the collection routes unlike the current existing system reducing human work load. In addition, the system is also made automated for the opening and closing of the lid using ultrasonic sensor and DC motor which make use of timing belt for opening and closing mechanism.

Keywords—IoT, Arduino, Ultrasonic sensor, Wi-Fi Module, DC Motor, Power supply.

I. INTRODUCTION

Internet of Things/IOT is a networking of physical object with the use of embedded electronic sensors and software that allows the devices to send and receive data from each other. The IOT performs sensing, gathering of data, storing the data and processing with the help of physical devices connected to the internet [14].

In this paper we are going to purpose a system to collect the garbage in real time using IoT. In the campus, although the garbage is being handled by municipal twice a week but the time for checking the garbage bin by responsible person has become insufficient because dustbin might get filled at any time which may or may not require immediate actions. This makes the system resources expensive and ineffectual as overflowing and stinking of dustbin has become more of problem than a solution [18].

The proposed system will help to monitor the garbage by sensing the filled level by ultrasonic sensor. When the garbage level crossed the marked level, the data is sent to the server through ESP2866 Wi-Fi module for the immediate action. The system is also equipped with automatic opening of the lid whenever the ultrasonic sensor senses the movement of the people coming near the dustbin to dump the waste with the help of DC motor.

II. RELATED WORKS

The deployment of modern technologies in the garbage bin is a growing trend. These technologies would mean automation in particular sense to stop

the overflow of garbage and to managed at real time. Many studies are being carried out by researchers to reduce/stop the overflow of garbage by the use of various electronic components.

Abdurahman, Aweke, et al. (2018) from Faculty of Electrical and Computer Engineering, Jimma University Institute of Technology, Ethiopia [10] explains the level of the garbage 2 being detected with the help of ultrasonic sensor and data being sent to the authorized agency through GSM. The system used PIR sensor to detect the motion of the people coming to the garbage bin and speaker to inform authorized agency about the status of the bin. The system also developed GUI to monitor the desired information related to the garbage bins for different selected locations. Depending on the received messages through the GSM at control room it is displayed on LCD and the authorized person inform the drivers to collect the garbage on time. This paper also discusses about notifying the people not to drop the waste outside dustbin by sensing their motion and If the dustbin is not cleaned in specific time, then the record is sent to the higher authorized office who can take appropriate action against the concerned contractor.

Chaware, Dighi, Akshaya et al, (2017) from Computer Department, BSCOER, Pune, India has proposed the system that monitors the garbage bins and informs about the level of garbage collected in the bins via a web page where it gives the graphical view of the bins and highlights the collected garbage by colors to show the level [11]. The system uses ultrasonic sensor to detect the garbage level, Arduino family microcontroller, LCD screen to display the status of the level, Wi-Fi modem for sending data and a buzzer. The system is powered by a 12V transformer. The system puts on the buzzer when the level garbage collected crosses the set limit.

Pathak, Nalawade, Kaundanya, & Parode, (2018) International Journal of Innovative Research in Science Engineering and Technology [13], published a paper which aims to describe the implementation of project called Garbage Level Monitoring System using Raspberry Pi in real time. This system consists of Raspberry pi, Ultrasonic sensor, ESP 8266 Wi-Fi Module and Power supply. When the power supply is given to the main processing unit, it runs the program and activates Ultrasonic sensor which will detects the level and the result is provided to the server. This provides administrator a visual report of waste level in all the garbage bins where he/she can take necessary action on that bin whose levels are above the threshold value.

Sharma, Singha, & Dutta et al, (2015) have equipped the smart bins with ultrasonic sensor. The dustbin was divided into three levels of garbage being collected in it. When garbage crosses a level, the sensor receives the data and sent to the garbage analyzer as the instant message using GSM module [15]. However, it requires a well-structured hardware. The onetime cost of installation will be higher than the present technique because GSM provide limited data rate capability and for higher data rate, advanced version devices are required.

In the paper ”Garbage and street Light Monitoring System using Internet Of Things” by Sahu, Akshaya et al, (2016) International Journal innovative Research in Electrical, Electronic, Instrumentation and control Engineering [16], have built a framework in which a camera will be set at each garbage collection point alongside load cell at base of the trash can. The camera will take continuous Snapshot of the garbage can. A threshold level is set which compares the output of camera and load sensor. The comparison is done with help of microcontroller. After analyzing the image and the load cell, an idea about level and weight of the garbage are known. Accordingly, information is Processed i.e. controller checks if the threshold level is exceeding or not. The method is expensive and practically not feasible.

With the consideration of all the related works carried out so far with regard to optimization/ reduction of overflow of garbage, this paper discusses on the simple technique i.e. deploy low cost, small size and reliable sensor units to monitor the garbage level. With reference to all the related works, this work is the combination and improvement from the related works carried out by other authors.

III. PROBLEM STATEMENT

The most concerned factor in present day to

day life is garbage production which has negative effect to the environment and improper disposal of garbage need to be addressed with suitable solution. Disposing of garbage on already filled dustbin has become a sort of routine due to growth of populations and incautious behavior of human beings. This creates issues to people's health. Additionally, the routine check of dust bin is not effective as it is time consuming because the concern people have to check and empty the dust bin whether it is filled or not. Moreover, if the dust bin remains unchecked for longer duration, overflowing and stinking of dust bin creates more problem than a solution. Hence, a proper monitoring system has become mandatory for an efficient and effective removal of the generated waste.

IV. METHODOLOGY

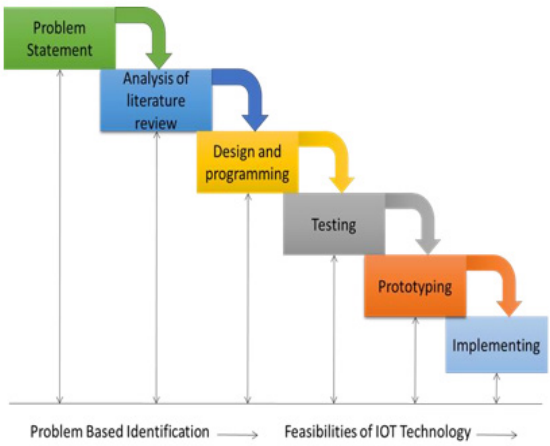

Figure 1: Methodology

V. SYSTEM ARCHITECTURE

The segregation part of the waste should be done by the users. This proposed system mainly focused on the monitoring of solid waste. The IOT Based Garbage Monitoring system is an innovative system which will help to keep the surrounding clean and healthy. The IoT enabled garbage bin and the model designed using Arduino is equipped with ultrasonic sensor which is placed vertically to detect the garbage level and compare it with the garbage depth and send to the controller and controller in turns communicates with the cloud server through the Wi-Fi module (ESP8266). The data sent by the bin is stored in the cloud and shows all dustbins level on the webpage in the form of graphical view and it is available for access from anywhere through the internet. Depending on the program the output will be generated by LCD screen which shows the status of garbage level and LED for the indication. Green light for ground level, orange for 50% and red for 100%. On receiving the notification over the website, the concerned department can send the respective team to collect the garbage. In additional, DC motor will be geared up for lid to be opened automatically for dumping service.

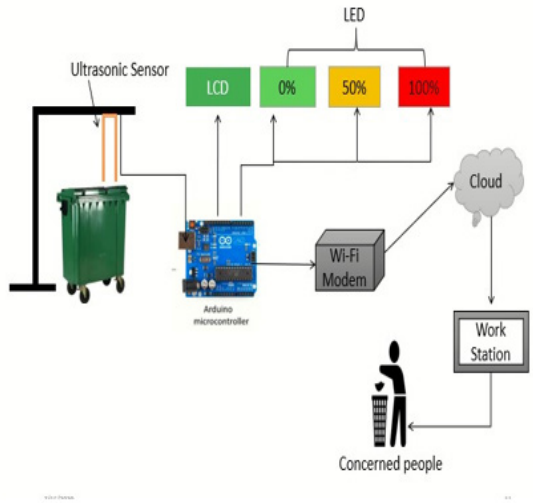

Figure 2: System Architecture

VI. FLOW CHART FOR AUTOMATIC LID OPENEING AND CLOSING

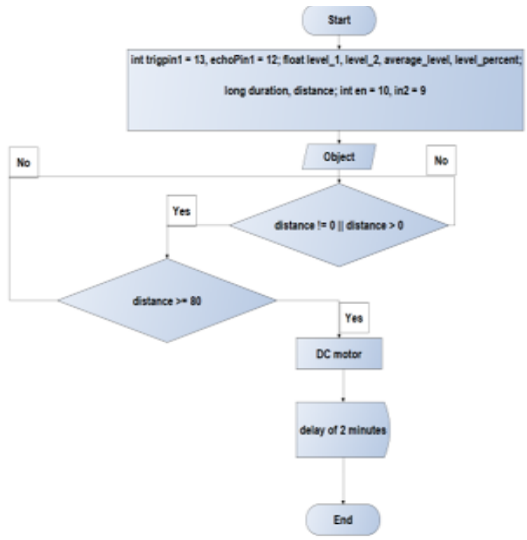

Figure 3: Flow Chart of Automatic Lid opening and closing

VII. FLOW CHART FOR LEVEL DETECTION

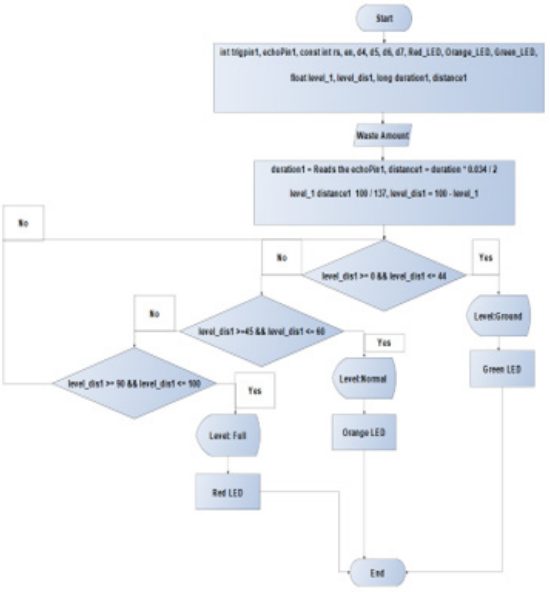

Figure 4: Flow Chart of Level Detection

VIII. SIMULATION

The system was simulated using Proteus Design Suite 8.0 as shown in figure 3 and 4 below for opening of lid and level detection respectively. It is quite hard to simulate both the system together as the system become more complex. Thus, in order to see the simulation results, potentiometer together with the virtual terminal are used to simulate at instant when the threshold level is reached. Varying in potentiometer value indicates that the distance between the dust bin and people is either increasing or decreasing. Simultaneously, the virtual terminal helps in serial monitoring.

1. Automatic lid opening and closing

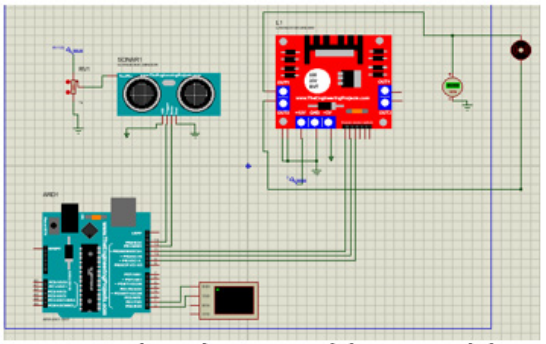

Figure 5: Simulation for Automatic lid opening and closing

2. Level Detection

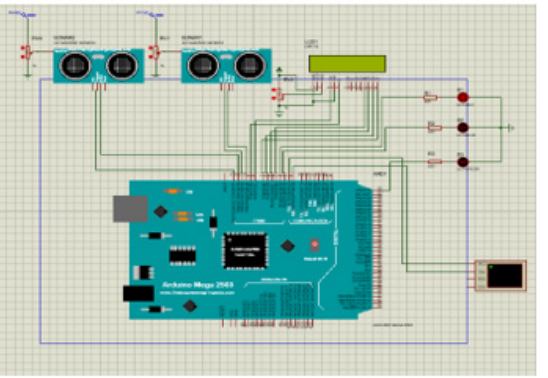

Figure 6: Simulation for Level Detection

IX. COMPONENT USED

The system uses following components:

Total of three Ultrasonic sensor are used. Two for the garbage level measurement and one for the automatic lid opening and closing. Arduino is used as main controller, Liquid Crystal Display (LCD) for the percentage indication of garbage level and three Light Emitting Diode (LED) for the indications. ESP8266 Wi-Fi module is also used in the system for the internet connectivity to transfer the data to the cloud and DC Motor for the automatic lid opening with the help of timing belt.

X. SYSTEM DESIGN

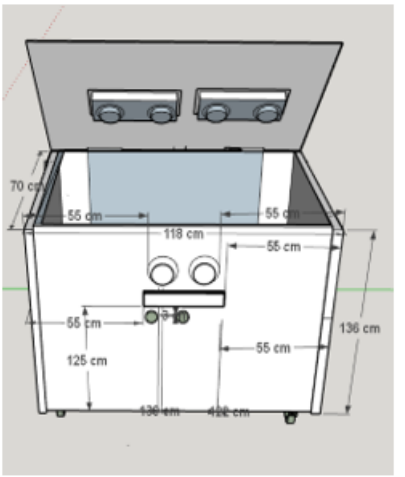

Figure 7: System Design

XI. SYSTEM TESTING

Before assembling all the components into one system, individual components were tested. The program code was uploaded to the assembled system.

XII. RESULT

a. Garbage level detection inside the dustbin

Using this project, the garbage level can be detected on the LCD and notification is been sent once the threshold level is reached.

b. The data can be accessed anytime and from anywhere

The data can be accessed through webpage, email and also by using the App Called ThingSpeak view.

c. Automatic opening of lid

The dustbin automatically opens the lid when the ultrasonic sensor senses the movement of the people coming near the dustbin.

The graph below depicts the output given by the sensor.

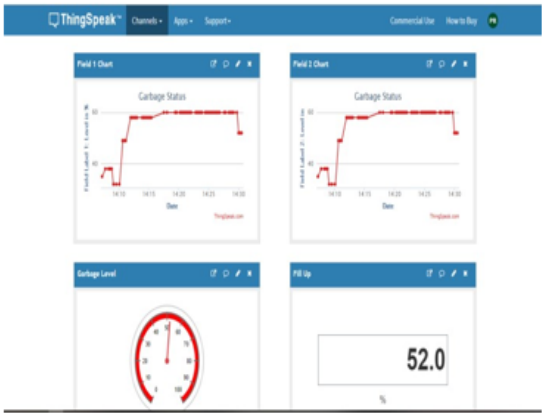

Figure 8: Web view of the person in charge when level is 52%

XIII. FUTURE SCOPE

The project can be extended to detect the wet waste in the bin by letting the worker know about the moisture contained in the bin to measure the level of liquid waste in industries. To get precise information, system can integrate with GPS module to locate the targeted garbage bin. It can work with rechargeable batteries/solar panel to make system more power reliable. This system can be used in certain area but as soon as it proves its credibility, it can be used in all the big area.

XIV. ADVANTAGES

This System will help to monitors the garbage bins effectively by detecting the garbage level and compare it with the garbage bins depth. The system informs about the level of garbage collected in the garbage bins. Help in optimizing the garbage management system. It is reliable and one of the good methods to monitor the garbage.

XV. CONCLUSION

Implementation of IoT based garbage monitoring system will help to check the level of filled dustbins. In this system the information of dustbins can be accessed from webpage, email or through ThingSpeak viewer app by the user and can take an immediate action. By implementing this system, the cost reduction, resource optimization and effective usage of dustbins can be done. This system will inform the status of dust bin in real time located throughout the campus so that the concerned authority can inform the garbage collection vehicle only when the dustbin is completely full or is about to full. Thus, the integrated IoT system is very useful to remotely monitor the garbage levels in dustbins which reduces cost and saves time. This system also reduces human efforts and is user- friendly system.

XVI. RECOMMENDATION

The system is limited with the accuracy of ultrasonic sensor. We would like to recommend to the future researchers to opt for better accuracy of the ultrasonic sensor. This will help in better monitoring and more advanced knowledge in programming and sensor as well.

XVIII. REFERENCES

[1] F. Abdurahman, C. Asefa and S. Aweke, “Automated Garbage Monitoring System Using Arduino,” IOSR Journal of Computer Engineering (IOSR-JCE), vol. 20, no. 1, pp. 64-76 , 2018.

[2] P. D. S. M. Chaware, S. Dighe, A. Joshi, N. Bajare and R. Korke, “Smart Garbage Monitoring System using Internet of Things (IOT),” International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control

Engineering, vol. 5, no. 1, pp. 74-77, january 2017.

[3] P. R. Rao, S. S. Kumar and C. R. Prasad, "Garbage Monitoring System using Arduino," International Journal of Trend in Scientific Research and Development (IJTSRD), vol. 1, no. 6, pp. 808-811, October 2017.

[5] H. A. Gawad, S. Kadam, D. Jain and N. Patel, "An IOT based Dynamic Garbage Level Monitoring System using Raspberry-pi," Int. Journal of Engineering Research and Application, vol. 7, no. 7, pp. 30-34, 2017.

[6] N. Sharma, N. Singha and T. Dutta, "Smart Bin Implementation for Smart Cities," International Journal of Scientific & Engineering Research, vol. 6, no. 9, 2015.

[7] K. Pokalekar, A. Salunkhe and P. Kachare, "IOT Based Garbage Monitoring System," International Research Journal of Engineering and Technology (IRJET), vol. 5, no. 3, pp. 3060-3062 , 2018.

[8] P. Sahu, A. Godase, P. Shinde and R. Shinde, "Garbage and Street Light Monitoring System Using Internet of Things," Internatioanl Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering, vol. 4, no. 4, pp. 107-110, 2016.

[9] P. Sultana, S. Challa and S. Jayavel, "IOT Based Garbage Monitoring System," Internationa l Journal of Pure and Applied Mathematics, vol. 116, no. 12, pp. 127-135, 2017.

[10] c. Phanindra, M. Kalyan, C. B. Sruthi, M. Shameem, L. Bai and C. R. K. Reddy, "Garbage Waste Monitoring System using Ultrasonic Sensor on FPGA," International Journal of Research in Applied Science & Engineering Technology (IJRASET), vol. 6, no. 4, pp. 1-5, 2018.

[11] N. M. Yusof, A. Z. Jidin and M. I. Rahim, "Samrt Garbage Monitoring System for Waste Management," MATCe Web of Conferences, pp. 1-5, 2016.

[12] P. A. Jadhao, S. D. Sakhare, K. G. Bhaldane, A. P. Narkhede and V. S. Girnale, "Smart Garbage Monitoring and Collection System using Internet of Things," Internationl Journal of Advance Engineering and Research Development, vol. 5, no. 6, pp. 1-8, 2018.

[13] N. Willie, K. Lucy, K. Shadrick and P. D. Victor, "GSM and GPS Based Garbage and Waste Collection Bin Overflow Management System for Kitwe City Council," International Journal of Engineering Research & Technology (IJERT), vol. 7, no. 4, pp. 55-61, 2018.

[14] M. N. Rajaprabha, p. Jayalakshmi, R. V. Anand and N. Asha, "IOT Based Smart Garbage Collector for Smart Cities," International Journal of Civil Engineering and Technology (IJCIET), vol. 9, no. 12, p. 435–439, December 2018.

[15] M. R. D. Bondad, J. M. S. Borcer and K. V. C. Lopez, "Auto-Bin: Automatic Lid Opening Trash Bin with Content Monitor," [Online]. Available: https://www.academia.edu./37075330/Auto-Bin_Automatic_Lid_Opening_Trash_Bin_Content_Monitor?auto=download&email_work_card=download-paper. [Accessed 9 may 2020].

[16] M. A. Anwar, P. Sarkar, R. Dutta and M. S. M. Mollick, "IOT BASED GARBAGE MONITORING USING ARDUINO," Beliaghta, Kolkata, 2018

[17] V. M. Rao, D. M. S. S. Ram and D. M. N. Giriprasad, "A Review- On IOT Based Garbage Monitoring and Collection System," International Journal of Advanced in Management, Technology and Engineering Sciences, vol. 7, no. 12, pp. 358-375, 2017.

[18] M. V. Patil and S. M. Gajbhiye, "A Review on Internet of Things Based Garbage Bins Detection Systems," International Journal of Science and Research (IJSR), vol. 6, no. 4, pp. 1699 -1702 , April 2017.

Load Frequency Control of Interconnected Power System Grid Involving Wind and Hydropower Plant and Comparative Analysis

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Abstract*—Demand for power is reliably expanding day by day. The greatest test is to give continuous and top-notch power to clients in factor conditions particularly when we interconnect the two areas utilizing power tie-line. To achieve this, the two boundaries should consistently be checked for each condition, these boundaries are Load Distribution and Load Frequency Control (LFC).The primary work of the load frequency control is to regulate the power output of the generator within a specified area with respect to change in system frequency and tie-line power, such as to maintain the scheduled system frequency and power interchange with other areas in a prescribe limits[1][2]. In this project, study of LFC system for two areas consisting of Hydropower Plant and Wind Power Plant are carried out. The fuzzy gain scheduled proportional-integral (FGSPI) and fuzzy gain scheduled proportional integral derivative (FGSPID) controllers are designed for load frequency control (LFC) of two-area interconnected power system. The proposed FGSPI and FGSPID controllers are compared against conventional proportional-integral (PI) controller and Proportional integral derivation (PID) controller with respect to settling times and peak overshoots of the tie-line power and frequency deviations as performance indices. Comparative analysis indicates that the proposed intelligent controller gives better performance than conventional controllers. Simulations have been performed using Simulink toolbox in MATLAB.

***Keywords*—load frequency control, wind power plant, hydropower plant, two area network, area control error, PI, PID, fuzzy gain scheduling**

I. Introduction

The objective of the load frequency control (LFC) is to maintain the scheduled frequency and scheduled tie-line power in a normal mode of operation, during the small perturbation in operating conditions. The input mechanical power is used to control the frequency of the generators and the change in the frequency and tie-line power are sensed, which is a measure of the change in rotor angle. A well-designed power system should be able to provide the acceptable levels of power quality by keeping the frequency and voltage magnitude within tolerable limits [3]. The enormous interconnected power systems are made out of control areas that represents to a different unit of generators. The different areas are interconnected through tie-lines. The tie-lines are utilized for exchanging the power between the consecutive two-areas and provides inter-area support in case of abnormal conditions of the power system.

Number of conventional controllers like Proportional(P), Integral(I), Proportional Integral (PI) and Proportional Integral Derivatives (PID) are utilized in a control system for controlling frequency deviation and tie-line power, as these controllers are simple to implement, easy to understand and have low cost. Nature of their control technique is dependable and announced as vigorous for some working conditions [4]. However, the response of system with these controllers is slow and poor in comparison to the intelligent controller. Zadeh presented fuzzy set hypothesis and the first fuzzy logic control algorithm was implemented by Mamdani on a steam motor. The enormous, complex and interconnected power systems suffer with countless nonlinear properties subsequently, fuzzy logic controller is one of the better controllers for the systems [5]. In this paper, Chhukha Hydro Power Plant and Rubesa Wind Power Plant are taken as the two-area network for

frequency and power deviation control. The FGSPI and FGSPID controllers and conventional controllers (PI and PID) are used for LFC and they are compared base on their settling time and peak overshoot.

II. System Modelling

In this paper Hydropower Plant and Wind Power Plant were taken as Area-1 and Area-2 respectively. Area-1 consist of four units and Area-2 with two unit. The system model consists of hydro-governor, wind turbine, hydro turbine and generators of both wind and hydro power plant and each component is represented in transfer function. The speed regulation constant and frequency bias factor are the feedback to the system. The frequency deviation Δf1 is for Area-1 and Δf2 for Area-2. ΔPL1 and ΔPL2 are the power demand increment for Area-1and Area-2 respectively and it is given in step load form. They Area-1 and Area-2 are interconnected by the tie line power. The area control error (ACE) for the two area is given to the two controllers [19]. ACE is given in the equation (1).

$$ACE_i = \sum_{j=1}^{n} \Delta P_{tie,ij} + B_i \Delta f_i \quad (1)$$

$$\text{Where, } Bi = D_i + 1/R_i \quad (2)$$

Where:
ACE_i = area control error of the i^{th} area
Δf_i = frequency error of i^{th} area
$\Delta P_{tie,ij}$ = tie-line power flow error between i_{th} and j^{th} area
B_i = frequency bias coefficient of i_{th} area

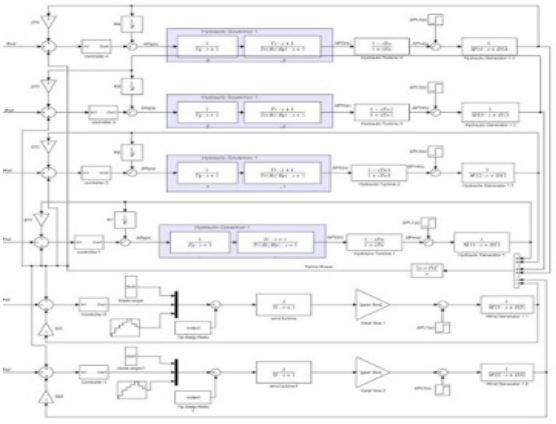

Figure 1. Two area multi-unit Hydro and Wind power system

III. Controllers

In this study, PI, PID, FGSPI and FGSPID controllers are used to control the load frequency and tie-line power of the two-area network. The conventional controller PI and PID are compared with the proposed hybrid FGSPI and FGSPID controllers.

A. PI Controller

The proportional integral controller produces an output, which is the combination of outputs of the proportional and integral controllers. PI controller will eliminate forced oscillations and steady state error resulting in operation of on-off controller. PI controllers are very often used in industry, especially when speed of the response is not an issue [23].

The value of the controller output u(t) is fed into the system as the manipulated variable input. Output power equals to the sum of proportion and integration coefficients[24].

$$u(t) = K_p e(t) + K_I \int e(t)dt \quad (3)$$

Apply Laplace transform on both sides

$$U(s) = (K_p + \frac{K_I}{s})E(s) \quad (4)$$

$$U(s)/E(s) = K_p + \frac{K_I}{s}S \quad (5)$$

Therefore, the transfer function of proportional integral controller is KP+KIs.

The block diagram of the unity negative feedback closed loop control system along with the proportional integral controller is shown in the figure 2.

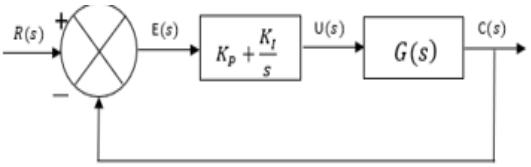

Figure 2. Schematic diagram of PI controller

The proportional integral controller is used to decrease the steady state error without affecting the stability of the control system.

B. PID Controller

The PID algorithm is most commonly used feedback controller. It is a robust easily understood algorithm that can provide excellent control

performance despite the varied dynamic characteristic of process. As the name suggest, the PID consist of three basic modes namely the proportional, integral and derivatives mode. When utilizing the PID algorithm it is necessary to decide which mode to be used (P, I & D) and then specify the parameter for each mode used. Generally, three basic algorithm P, PI and PID are used to automatically adjust some variables to hold a measurement to a desired variable [25][26].

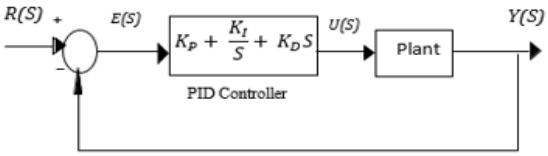

Figure 3. Schematic diagram of PID controller

The output of PID controller in time domain

$$u(t) = K_p e(t) + K_I \int e(t)dt + Kd\, d/dt\, e(t)$$

Taking the Laplace on both the side:

$$U(s) = (K_P + \frac{K_I}{S} + K_D S)E(s) \quad (6)$$

$$\frac{U(s)}{E(s)} = (K_P + \frac{K_I}{S} + K_D S) \quad (7)$$

$$\frac{U(s)}{E(s)} = \frac{K_D S^2 + K_P S + K_I}{S} \quad (8)$$

Whereas, E(s) and U(s) are the input and output of the plant respectively.

a. Ziegler-Nichol's Tuning Method

Ziegler and Nichols created two strategies for controller tuning during the 1940s. The idea was to tune the controller dependent on the following idea: Make a simple experiment, extract some features of process dynamics from the experimental data, and determine controller parameters from the features [27][28][29]. The following processes are followed:

- Increase the gain until the loop starts oscillating. Note that linear oscillation is required and that it should be detected at the controller output.
- Record the controller critical gain Kp = Kc and the oscillation period of the controller output, Pc.
- Adjust the controller parameters according to Table given below.

TABLE I: ZIEGLER-NICHOLS TUNING RULE BASED ON CRITICAL GAIN Kc AND CRITICAL PERIOD Pc

	Kp	Ti	Td
P Controller	0.5Kc	∝	0
PI Controller	0.45Kc	Pc/1.2	0
PID Controller	0.6Kc	0.5Pc	Pc/8

Simultaneously, the value of Ki and Kd can be calculated using the following formula:

$$K_i = K_p/T_i \quad (9)$$

$$K_d = K_p * T_d \quad (10)$$

Whereas, Ti and Td are the Integral time and Derivative time respectively.

C. Fuzzy Gain schedule PI and PID cotrollers

Gain scheduling is the common techniques use in the system whose dynamic changes non-linearly with operation conditions. Here, the fuzzy logic set supervise and modifies the operations, i.e., gain scheduling of the conventional controllers. FGSPI and FGSPID controllers are designed and used to control the frequency deviation of two area network[30]. The design of FGSPI and FGSPID controllers can be divided into three parts:

- The allocation of the proper inputs
- The determination of the rules associated with inputs
- The defuzzification of the output

a. Fuzzification

In this process the precise numerical values obtained by measurement are converted to membership values of the various linguistics. For this controller the two inputs are the Area control Error (ACE) and the change in error [d/dt (ACE)] [31].

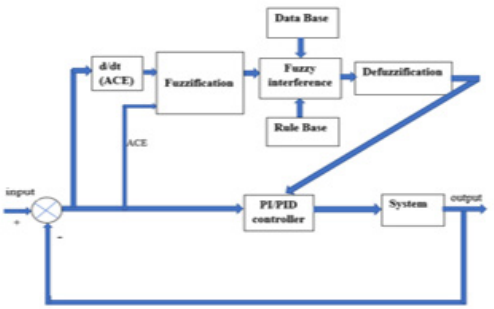

Figure 3. Schematic diagram showing the working processes of FGSPI and FGSPID Controller

b. Fuzzy Rule Base

For the proposed controller, the Mamdani method was selected and realized by five triangular membership functions for each of the three linguistic variables (ACE d/dt(ACE), K) with suitable choice of intervals of the membership functions, where ACE and d/dt(ACE) act as the inputs of the controller and K is the output of the controller. In table II below, NB, NS, Z, PS, PB represent negative big, negative small, zero, positive small, and positive big respectively. The rule base has been formed in such a manner. For example; If ACE is NB and d(ACE)/dt is NB then the controller action is PB [33]. The appropriate rules used in the study are given in table II.

TABLE II: FUZZY LOGIC RULE FOR FGSPI AND FGSPID CONTROLLER

	ACE					
		NB	**NS**	**Z**	**PS**	**PB**
d/dt(ACE)	**NB**	PB	PB	PB	PB	Z
	NS	PB	PB	PS	Z	Z
	Z	PS	PS	Z	NS	NS
	PS	Z	Z	NS	Z	NB
	PB	Z	NS	NB	NB	NB

c. Defuzzification

The transformation of a fuzzy set into a numeric value is called defuzzification. Before feeding the data to the system it is very much important to do the defuzzification of the fuzzy set. The data needs to converted into the numerical value from membership function before feeding to the system[35]. The output from the fuzzy logic controller is use to schedule the gain of PI and PID controller.

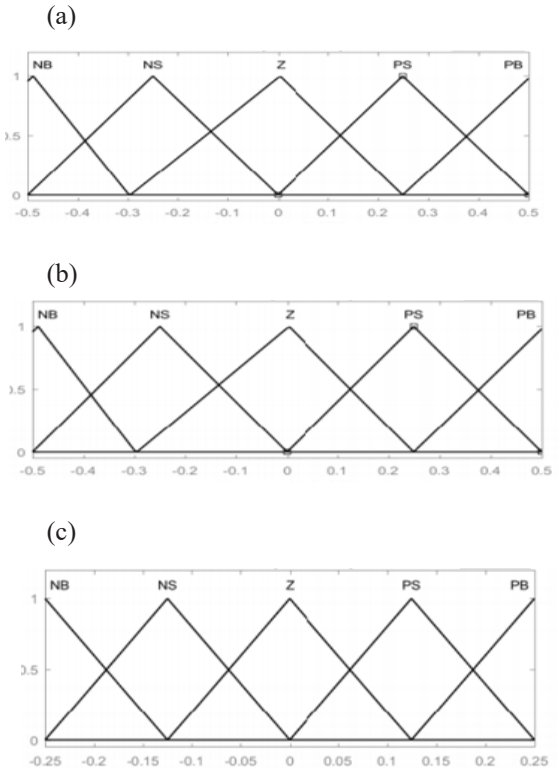

Figure 4. Membership Function for FGSPI and FGSPID Controller of (a) ACE, (b) ΔACE and (c) output

IV. SINULATION RESULT AND DISCUSSION

The load frequency control of two area network was carried out using different controllers. The step load disturbance of 0.1 p.u. was applied in area-1 and the deviations in frequency and tie-line power flows were investigated. The conventional controllers like PI and PID controllers are used. The conventional controllers are compared with the proposed hybrid-type controllers like FGSPI and FGSPID controllers. The simulation of the two-area model with different controllers was carried out using the simulation toolbox in MATLAB. The simulated results were compared on the peak overshoot and the settling time of the output frequency.

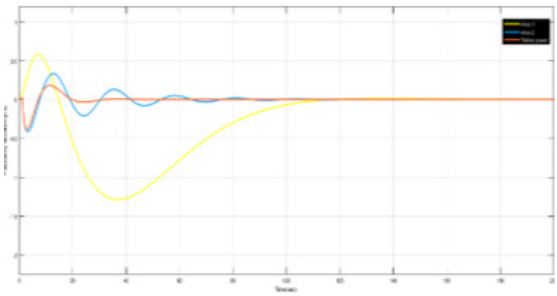

Figure 5. Simulated result with PI controller

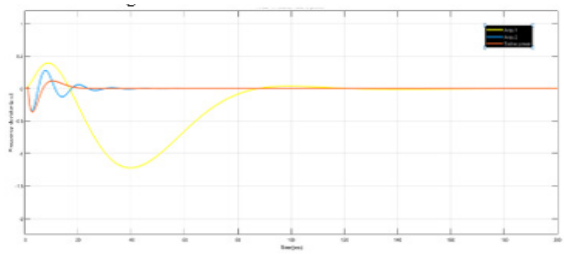

Figure 6. Simulated result with PID controller

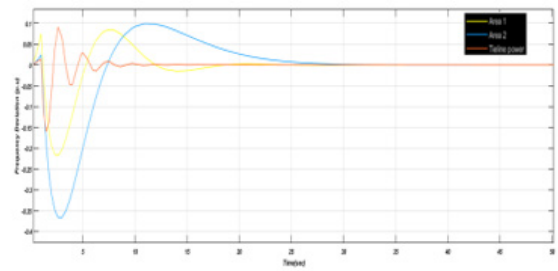

Figure 7. Simulated result with FGSPI controller

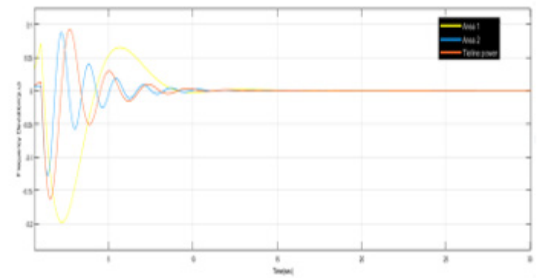

Figure 8. Simulated result with FGSPID controller

The quantitative comparative analysis of the results with respect to frequency and tie-line power deviations for different controllers are given in Table III. The performance indices used are peak overshoot and settling time. As it is clear from Table III, that the response with FGSPID controller is the best among all the controllers, because the values of peak overshoot and the settling time are minimum in case of FGSPID controller.

TABLE III: COMPARATIVE ANALYSIS OF RESULTS

Controllers	Areas	Peak Overshoot (p.u)	Settling Time (Sec)
PI Controller	Area-1	0.58	115
	Area-2	0.35	100
	Tie-lie power	0.15	30
PID Controller	Area-1	0.40	110
	Area-2	0.26	40
	Tie-lie power	0.12	20
FGSPI Controller	Area-1	0.08	18
	Area-2	0.10	28
	Tie-lie power	0.09	12
FGSPID Controller	Area-1	0.07	10
	Area-2	0.09	12
	Tie-lie power	0.08	11.5

V. CONCLUSUON

In this research project, the conventional controllers (PI and PID) and propose hybrid types controllers (FGSPI and FGSPID) approach are employed for load frequency control of an inter-connected power system involving Chhukha Hydropower plant and Rubesa Wind power plant. The system was simulated using the Simulink toolbox in MATLAB. The proposed hybrid types of controllers like FGSPI and FGSPID are reported as with better performance (dynamic response improvement) in comparison to conventional controllers like PI and PID controllers. The system response is compared in terms of the peak overshoot (p.u) value and the settling time (sec). The proposed controllers are not only simple in design but also easy to implement. Moreover, on-line adaptation of supplementary controller gain makes the proposed controllers more effective and it is expected that the controller will perform effectively under different operating conditions. Simulation results obtained demonstrate

the usefulness of the proposed controllers. Taking PI and FGSPID controllers into consideration the peak overshoot in Area-1, Area-2 and tie-line power was reduced by 87%, 74% and 46% respectively. Similarly, the settling time in Area-1, Area-2 and tie-line power was reduced by 91.3%, 88% and 61.6% respectively. From the research that has been carried out it is possible to conclude that the proposed hybrid type FGSPID controller had a faster respond to the system feedback error and it can be implemented to the system where a fast respond is required.

VII. REFERENCES

[1] Sathans and A. Swarup, "Intelligent load frequency control of two-area interconnected power system and comparative analysis," Proc. - 2011 Int. Conf. Commun. Syst. Netw. Technol. CSNT 2011, no. December, pp. 360–365, 2011, doi: 10.1109/CSNT.2011.81.

[2] M. R. Tur, M. Wadi, A. Shobole, and S. Ay, "Load Frequency Control of Two Area Interconnected Power System Using Fuzzy Logic Control and PID Controller," 7th Int. IEEE Conf. Renew. Energy Res. Appl. ICRERA 2018, vol. 5, pp. 1253–1258, 2018, doi: 10.1109/ICRERA.2018.8566890.

[3] D. Sambariya and V. Nath, "Load Frequency Control Using Fuzzy Logic Based Controller for Multi-area Power System," Br. J. Math. Comput. Sci., vol. 13, no. 5, pp. 1–19, 2016, doi: 10.9734/bjmcs/2016/22899.

[4] A. Sreenath, Y. R. Atre, and D. R. Patil, "Two area load frequency control with fuzzy gain scheduling of PI controller," Proc. - 1st Int. Conf. Emerg. Trends Eng. Technol. ICETET 2008, pp. 899–904, 2008, doi: 10.1109/ICETET.2008.255.

[5] B. A. Reddy, Y. Srinivas, and E. Venkata Ramesh, "Analytical structures of gain-scheduled fuzzy PI controllers," 2010 Int. Conf. Ind. Electron. Control Robot. IECR 2010, pp. 122–128, 2010, doi: 10.1109/IECR.2010.5720138.

[6] O. R. Hydraulic, S. E. T. P. Adjustmnets, F. B. Transmitter, S. F. Pt, and G. Or, "CHAPTER-6 HYDRO-TURBINE GOVERNING SYSTEM (Reviewed by Dr . R . Thapar)," vol. II, pp. 147–173.

VI. APPENDIX

Parameter	Description	Value	Unit
T_g	Time constant of governor of Area-1	5	Second
T_R	Reset time of governor of Area-1	10	Second
T_w	Water starting time of Hydro turbine in Area-1	15.8	Second
H_1	Inertia constant of generator of Area-1	3.04	MW.sec/MVA
D_1	Load damping constant Area-1	1	
R	Droop Characteristic of Area-1	10	Hz/pu MW
β_1	Frequency bias factor of Area-1	1.1	pu MW/Hz
ρ	Air density of Area-2	1.20735	Kg/m^3
V	Wind velocity of Area-2	Variable	m/s
T_t	Wind Turbine time constant	7.5	sec
C_p	Power coefficient of Area-2	0.53	
λ	Tip speed ratio	5.79	
θ	Pitch Angle	35.5	Degree
β_2	Frequency bias factor of Area-2	0.56	pu MW/Hz
G	Gearbox Ratio	1:120	
H_2	Inertia constant of wind generator of Area-2	3.79	MW.sec/MVA
D_2	Load Damping constant of Area-2	1	
r	Blade length	16.5	meter
T	Synchronizing Coefficient for Tie Line for Two Area Systems	0.08	MW/radian

[7] N. K. Kumar and I. E. S. Naidu, "Load Frequency Control for A Multi Area Power System Involving Wind , Hydro and Thermal Plants," vol. 3, no. 1, pp. 1008–1013, 2014.

[8] Woodward, “Speed Droop and Power Generation,” Power, vol. 01302, 1991.

[9] S. Chaudhary, “Load Frequency Control For Distributed Grid Power System Single Area & Multi-area System.”

[10] O. Beltran, R. Peña, J. Segundo, A. Esparza, E. Muljadi, and D. Wenzhong, “Inertia estimation of wind power plants based on the swing equation and Phasor Measurement Units,” Appl. Sci., vol. 8, no. 12, 2018, doi: 10.3390/app8122413.

[11] A. K. Sahoo, V. Chitra, and T. Kanagapriya, “Load Frequency Control for a Distributed Grid System Involving Wind and Hydro Power Generation,” 2012.

[12] P. S. Kundur, “(P.Kundur-1)Power System Stability and Control Volume I,” McGraw-Hill, Inc. pp. 1–600, 2004.

[13] N. Nguyen and J. Mitra, “Effect of wind power on load frequency control,” IEEE Power Energy Soc. Gen. Meet., vol. 2016-Novem, 2016, doi: 10.1109/PESGM.2016.7741814.

[14] E. F. Richards, “Dr. Earl F. Richards,” 1990.

[15] A. J. Mahdi, W. H. Tang, and Q. H. Wu, “Derivation of a complete transfer function for a wind turbine generator system by experiments,” PEAM 2011 - Proc. 2011 IEEE Power Eng. Autom. Conf., vol. 1, no. September, pp. 35–38, 2011, doi: 10.1109/PEAM.2011.6134789.

[16] P. P. Komarnicki, “Topic : Wind Power - Modeling • Control System Modeling Maximizing of Energy Yield,” 2019.

[17] A. Mohanty, M. Viswavandya, D. Mishra, and S. Sthitapragyan, “Modeling and optimization of remote solar - Wind hybrid station for stability & reactive power management,” Proc. - 2015 Int. Conf. Man Mach. Interfacing, MAMI 2015, pp. 1–6, 2016, doi: 10.1109/MAMI.2015.7456590.

[18] A. Kalmikov, “Wind Power Fundamentals,” Wind Energy Eng. A Handb. Onshore Offshore Wind Turbines, pp. 17–24, 2017, doi: 10.1016/B978-0-12-809451-8.00002-3.

[19] Y. Zhang, X. Liu, and Y. Yan, “Model predictive control for load frequency control with wind turbines,” J. Control Sci. Eng., vol. 2015, 2015, doi: 10.1155/2015/282740.

[20] G. Singh and S. K. Sinha, “Frequency and tie-line power control of two area network with multi sources of generators,” India Int. Conf. Power Electron. IICPE, vol. 2016-Novem, 2016, doi: 10.1109/IICPE.2016.8079333.

[21] چ. رسولی, “No Title رساله دکتری دانشگاه شهید بهشتی.”

[22] Y. Mi et al., “Sliding mode load frequency control for multi-area time-delay power system with wind power integration,” IET Gener. Transm. Distrib., vol. 11, no. 18, pp. 4644–4653, 2017, doi: 10.1049/iet-gtd.2017.0600.

[23] S. K. Vavilala, R. S. Srinivas, and M. Suman, “Load Frequency Control of Two Area Interconnected Power System Using Conventional and Intelligent Controllers,” vol. 4, no. 1, pp. 156–160, 2014.

[24] K. Bedoud, M. Ali-Rachedi, T. Bahi, and R. Lakel, “Adaptive Fuzzy Gain Scheduling of PI Controller for control of the Wind Energy Conversion Systems,” Energy Procedia, vol. 74, pp. 211–225, 2015, doi: 10.1016/j.egypro.2015.07.580.

[25] P. Gopi and G. Suman, “A new approach for Tuning of PID Load Frequency Controller of an Interconnected Power System,” Int. J. Mod. Trends Eng. Res., 2015.

[26] R. R. Bajya and M. R. Taparia, “Modeling of a nonlinear hydro power plant and analysis with PID controllers,” ICCCCM 2016 - 2nd IEEE Int. Conf. Control Comput. Commun. Mater., no. Iccccm, pp. 16–18, 2017, doi: 10.1109/ICCCCM.2016.7918262.

[27] S. R. Krishna, P. Singh, and T. I. T. Excellence, “International Journal of Current Trends in Engineering & Technology Optimal Design & Analysis of Load Frequency Control for two Interconnected Area , Using PSO as Smart Tool to Tune PID,” vol. 02, pp. 2–5, 2016.

[28] A. T. Hammid, M. Hojabri, M. H. Bin Sulaiman, A. N. Abdalla, and A. A. Kadhim, “Load Frequency Control for hydropower plants using PID controller,” J. Telecommun. Electron. Comput. Eng., vol. 8, no. 10, pp. 47–51, 2016.

[29] A. I. Dounis, P. Kofinas, C. Alafodimos, and D. Tseles, “Adaptive fuzzy gain scheduling PID controller for maximum power point tracking of photovoltaic system,” Renew. Energy, vol. 60, pp. 202–214, 2013, doi: 10.1016/j.renene.2013.04.014.

[30] M. R. Nayeri, S. Khosravi, and M. Aliyari Sh., “Design and implementation double input fuzzy PI and fuzzy gain scheduling PI controller on hydraulic plant,” 13th Iran. Conf. Fuzzy Syst. IFSC 2013, 2013, doi: 10.1109/IFSC.2013.6675648.

[31] H. D. Mathur and H. V. Manjunath, “Extended fuzzy logic based integral controller for three area power system with generation rate constraint,” Proc. IEEE Int. Conf. Ind. Technol., pp. 917–921, 2006, doi: 10.1109/ICIT.2006.372279.

[32] K. K. Swamy and K. C. Sekhar, “Comparative Analysis of Different Controllers in Two – Area Hydrothermal Power System,” pp. 493–501, 2017.

[33] F. U. Syed, M. L. Kuang, M. Smith, S. Okubo, and H. Ying, “Fuzzy gain-scheduling proportional-integral control for improving engine power and speed behavior in a hybrid electric vehicle,” IEEE Trans. Veh. Technol., vol. 58, no. 1, pp. 69–84, 2009, doi: 10.1109/TVT.2008.923690.

[34] M. S. Anower, M. R. I. Sheikh, M. F. Hossain, M. G. Rabbani, and A. B. M. Nasiruzzaman, “Fuzzy gain scheduling of an AGC in a single area power system,” Proc. 4th Int. Conf. Electr. Comput. Eng. ICECE 2006, no. December, pp. 9–12, 2007, doi: 10.1109/ICECE.2006.355277.

[35] S. Baghya Shree and N. Kamaraj, “Hybrid Neuro Fuzzy approach for automatic generation control in restructured power system,” Int. J. Electr. Power Energy Syst., vol. 74, no. 3, pp. 274–285, 2016, doi: 10.1016/j.ijepes.2015.05.029.

Installation of UPFC in Eastern Grid of Bhutan; Modelling, Simulation and Case Study

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***Abstract*—This paper intends to carry out the load flow analysis of the eastern grid of Bhutan in MATLAB using the PSAT toolbox. Some of the FACTS devices are implemented in the eastern grid after performing the initial load flow without their implementation. The improvement in performance capability of the eastern grid were determined after the implementation of the various FACTS devices.**

***Keywords*—FACTS Devices, Load Flow, Newton Raphson, Optimal Placement, STATCOM, SVC, UPFC.**

I. INTRODUCTION

With power demand increasing rapidly at the rate of 8% per annum, Bhutan Power system is becoming complex resulting in more contingences. It is expected to further increase the network after completing the on-going and upcoming transmission and hydro power projects. This has put vigilance on the capacity of the existing power system network and the provision of future expansion across the country and to India.[1]

With Power System network becoming bulkier and complex, Power system of Bhutan is facing a problem of the peak and complex power management. In order to reduce instability, losses and complexity of the system, the system requires power handling capabilities of the transmission lines at any conditions. Such conditions give rise to what is called Flexible Alternating Current Transmission System (FACTS) devices and why to go for it. FACTS devices are mainly used to increase Power transfer Capability, control and provide stability to the power system.

Among different types of FACTS devices, the 3rd generation FACTS, which is the combination of STATCOM and SSSC called Unified Power Flow Controller (UPFC) is considered as a comprehensive multivariable FACTS controller because it can individually or sequentially control all power system parameters, including voltage amplitude, line impedance and phase angle. It can also provide control of both active and reactive power in the transmission line.[2]

II. DIFFERENT TYPES OF FACTS IMPLEMENTED

A. Static Var Compensator (SVC)

Figure 1 shows that the transmission line voltage is flowing through the step-down transformer which is connected to the Thyristor Switch Capacitor (TCS) and Thyristor Control Reactor (TCR). Number of thyristors are connected in anti-parallel to each other in both TCS and TCR. The gating is control by controller which has the input parameter setting. By changing the thyristor conduction angle, it can control the compensator control voltage (i.e., voltage coming from potential transformer which has a fixed voltage). So, by changing the conduction angle of the thyristor, it can crack the compensative action as the compensator for capacitor compensator and induction compensator. [3]

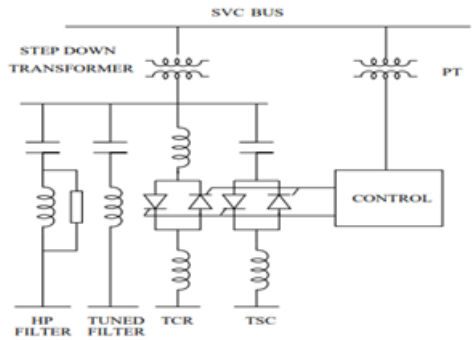


Figure 1. Schematic Diagram of SVC

B. STATCOM (Static Synchronous Compensator)

STATCOM stands for static synchronous compensator or condensers. It may be the source of reactive power or sink of reactive AC power. It can also provide active power when connected to source of power. It is a shunt device which uses power electronic devices like GTO, IGCT, MCT or IGBT etc.

STATCOM is usually installed to improve the power factor and to improve voltage regulation. It is a voltage source converter (VSC). Basically, STATCOM consist of coupling transformer, power converter, reactors and controllers etc. It has lead-lag capability and has no moving parts. [4]

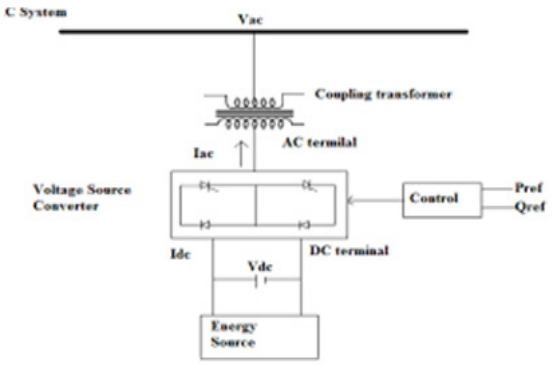


Figure 2. Schematic diagram of STATCOM

C. Static Synchronous Series Compensator (SSSC)

SSSC operates like series capacitor and series inductor. It works like the STATCOM but the STATCOM is connected in parallel and SSSC is connected in series so it is also called series STATCOM. If we use SSSC for transferring active and reactive power then large energy source is required for SSSC, so it is costly. Smaller supply source is useful for providing only reactive power. It provides fast control and is useful for power factor correction. It also reduces harmonic distortion by active filtering. It works on the principal that it can injects the voltage in series with the transmission line and control the impedance.

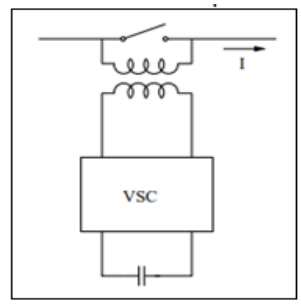
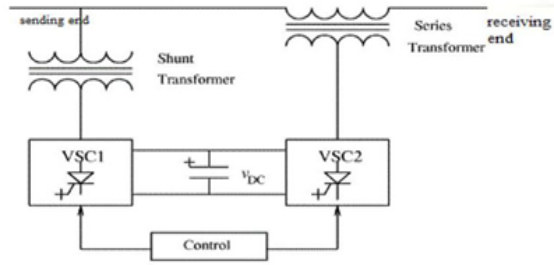


Figure 3. Schematic diagram SSSC

D. Unified Power Flow Controller (UPFC)

UPFC is the combination of STATCOM and SSSC which provides the greater flexibility of operation. UPFC is the most flexible and complex form of FACTS devices containing both the features of STATCOM and SSSC. UPFC is the third generation of FACTS and is more comprehensive FACTS devices in power system. In steady state, it can regulate the power flow by controlling line active and reactive power, improving the transmission capacity. In transient state, it can realize the fast-acting reactive power compensation, improving the system voltage stability. It can also improve power angle stability and damping of the system. In general, it regulates reactance in the line, phase angle and voltage.[2]



III. CLASSIFICATION OF BUSES

In a power system, each bus is associated with the following quantities;

1. Voltage Magnitude |V|.
2. Phase Angle .
3. Real power .
4. Reactive powers .

For load flow studies, two out of these are specified and remaining two are required to be determined through the solution of equation. Depending on the

quantities that have been specified, the buses are classified into three categories as shown in table 1. [5]

Table 1. Classification of Buses

Type of Bus	Specified Quantities	Unspecified Quantities	Number of Buses
Slack Bus	$\|V_1\|$ and $\delta_1 = 0$	P_1 and Q_1	Only one
PV Bus (Generator Bus)	P_1 and $\|V_i\|$	Q_1 and δ_1	15%
PQ Bus (Load Bus)	P_1 and Q_1	$\|V_i\|$ and δ_1	85%

IV. LOAD FLOW METHOD

From various types of load flow methods, Newton Raphson was selected and the algorithm is as in figure 5. [5]

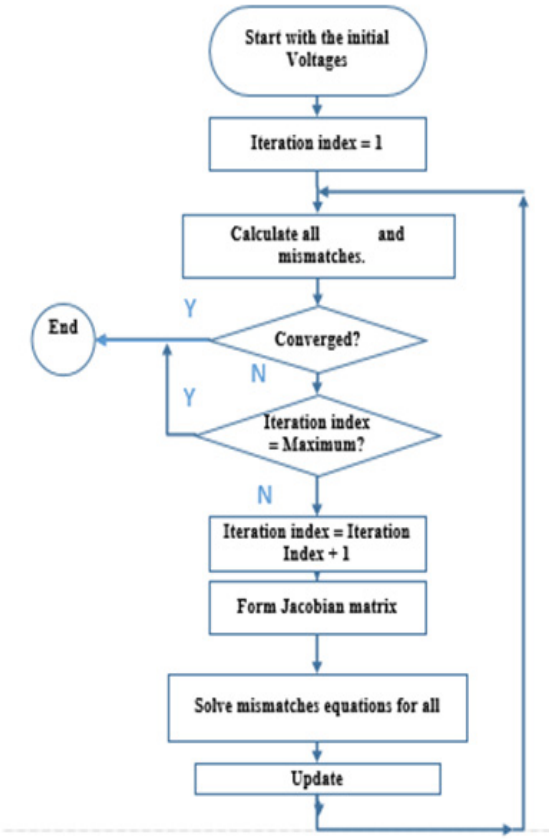


Figure 5. Load Flow Algorithm

V. MODELLING OF EASTERN GRID

Modelling of eastern grid of Bhutan was done without any FACTS devices initially and later on different types of FACTS devices were implemented to check the performance of each FACTS devices and to determine the improvement in voltage profile and compensation in power.

A. Without FACTS device

Figure 6 shows the model of 132kV buses of eastern grid of Bhutan without any FACTS devices.

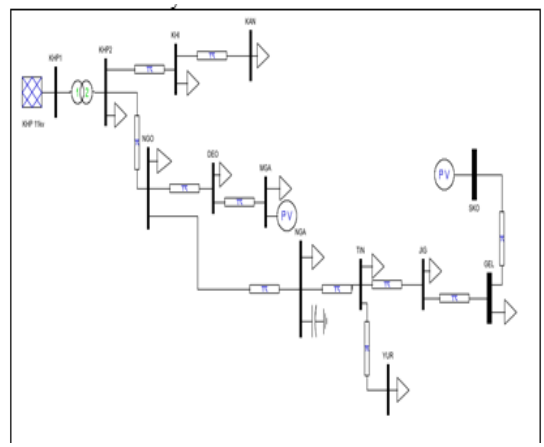


Figure 6. Eastern grid of Bhutan

B. Incorporating STATCOM

The following model is with the implementation of STATCOM in the eastern grid to check the performance of STATCOM.

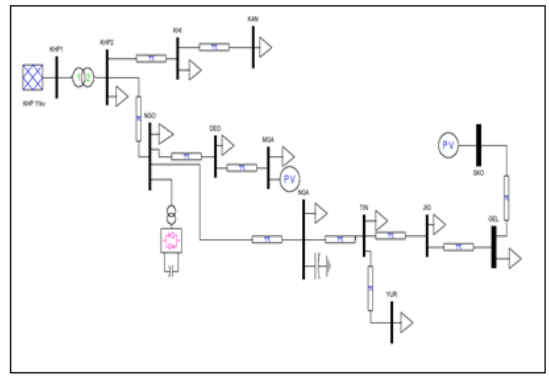


Figure 7. Eastern grid incorporating SVC

C. Incorporating SVC

The following model is after implementing SVC

in the eastern grid. The improvement in voltage and compensation of power will be discussed towards the end.

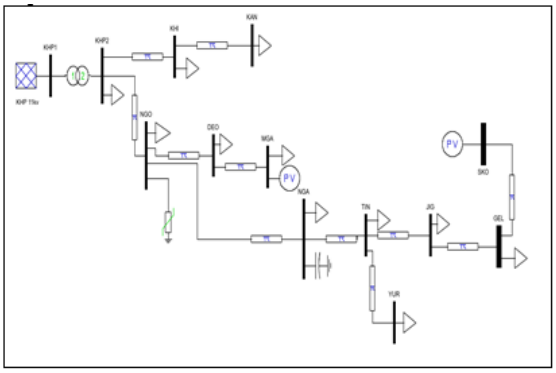


Figure 8. Eastern grid incorporating SVC

D. Incorporating UPFC

Figure 9 shows the model of 132kV buses of eastern grid after UPFC is implemented in the grid to improve voltage profile and compensate power losses.

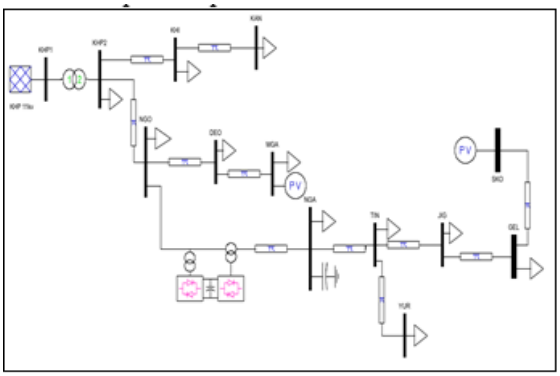


Figure 9. Eastern grid incorporating UPFC

E. Modelling of whole eastern grid

Figure 10 shows the model of the whole eastern grid considering 11kV, 33kV, 66kV and 132kV. In this model, FACTS devices are not implemented.

F. UPFC implemented in the whole grid

Figure 11 shows the whole eastern grid after implementing UPFC.

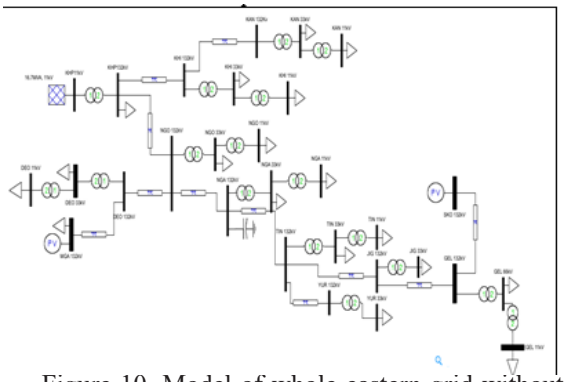


Figure 10. Model of whole eastern grid without FACTS

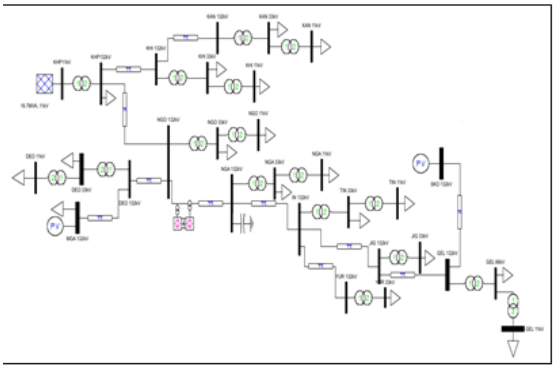


Figure 11. Model of whole eastern grid with UPFC

VI. RESULTS AND DISCUSSIONS

A. Model data validation with BPSO

Figure 12 shows the comparison waveform of voltage profile that was determined from the modelling for this research and that voltage profile of BPSO.

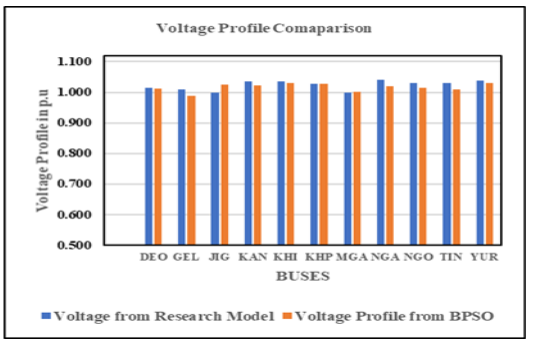


Figure 11. Voltage profile comparison with BPSO

B. Voltage profile comparison of 132kV buses

Figure 12 shows the voltage profile comparison of the above model that were done with and without implementation of the FACTS devices. As the model is not clear the enlarged model will be attached on the appendix section.

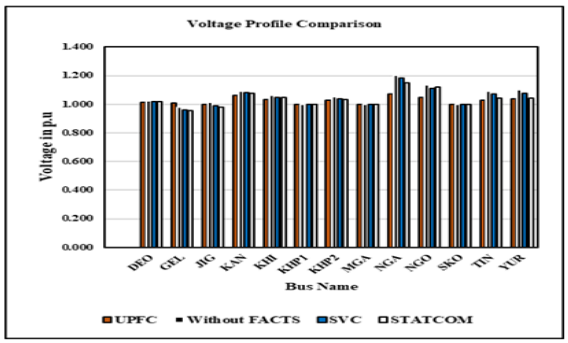


Figure 12. Voltage profile comparison of 132kV buses

C. Comparison of Real Power loss

Figure 13 shows the waveform of real power loss comparison in absence of UPFC and in presence of UPFC. It is clearly seen that there is at least compensation of 1MW

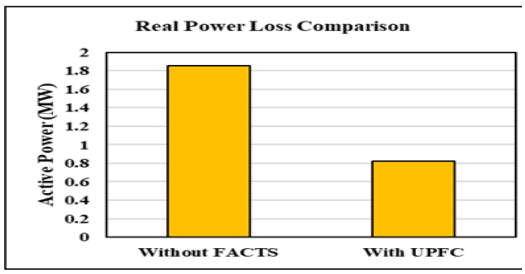


Figure 13. Real Power Loss

D. Comparison of Reactive Power loss

Figure 14 shows the waveform of reactive power loss in the eastern grid after implementing UPFC and before implementing UPFC.

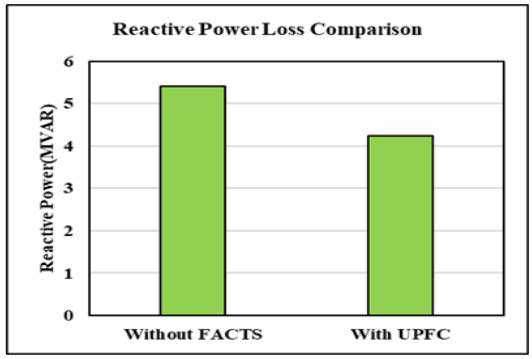


Figure 14. Reactive power loss comparison

VII. CONCLUSION

This project focuses on performance of proposed device (installation of UPFC and simulating in MATLAB PSAT) from the data acquired from BPSO for the year 2016-2019 and tested in eastern grid of Bhutan. FACTS device such as STATCOM and SVC have been simulated to compare the result with that of UPFC. From this research, the simulation results show that UPFC performs much better than the conventional transmission line (i.e. without any FACTS device incorporated in the grid) followed by STATCOM and SVC respectively. After incorporating UPFC in eastern grid of Bhutan, the grid becomes more stable with maximum utilization of the line (increase in real power and reduce in losses).

VIII. REFERENCES

[1] L. K. Chhetri and B. Sajjakulnukit, "A Study of Household Energy Consumption in Thimphu : Bhutan," vol. 9, pp. 65–71, 2018.

[2] M. Ткач, No TitleТайны католических монашеских орденов. .

[3] B. Oum, E. Fadhel, and M. Fellah, "The

Static Var Compensator (SVC) Device in the power systems Using Matlab / SimPowerSystems The Static Var Compensator (SVC) Device in the power systems Using Matlab / SimPowerSystems ICEPS laboratory (Intelligent Control & Electrical Power Systems)," no. February 2015, pp. 54–59, 2008.

[4] M. Takasaki, "Power transfer capability enhancement with UPFC under circumstances of uncertain power flow pattern," Proc. IEEE Power Eng. Soc. Transm. Distrib. Conf., pp. 659–665, 2006, doi: 10.1109/TDC.2006.1668575.

[5] C. K. Seng, T. L. Tien, J. Nanda, and S. Masri, "Load Flow Analysis Using Improved Newton-Raphson Method," Appl. Mech. Mater., vol. 793, no. March, pp. 494–499, 2015, doi: 10.4028/www.scientific.net/amm.793.494.

[6] B. Asadzadeh, V. Asadzadeh, S. H. Hosseini, and G. B. Gharehpetian, "Allocation of UPFC in North West grid of Iran to increase power system security," 2010 IEEE PES Transm. Distrib. Conf. Expo. Smart Solut. a Chang. World, pp. 1–8, 2010, doi: 10.1109/TDC.2010.5484193.

[7] D. Sen and P. Acharjee, "Optimal placement of UPFC based on techno-economic criteria by hybrid CSA-CRO algorithm," Asia-Pacific Power Energy Eng. Conf. APPEEC, vol. 2017-Novem, no. 1, pp. 1–6, 2018, doi: 10.1109/APPEEC.2017.8308909.

[8] F. M. Albatsh, S. Ahmad, S. Mekhilef, H. Mokhlis, and M. A. Hassan, "Optimal placement of unified power flow controllers to improve dynamic voltage stability using power system variable based voltage stability indices," PLoS ONE, vol. 10, no. 4. 2015, doi: 10.1371/journal.pone.0123802.

[9] R. Thota and S. Hameed, "Optimal location of Unified Power Flow Controller (UPFC) to control active power flows and congestion Management in a transmission lines by using Fuzzy Based," vol. 3, no. 5, pp. 77–82, 2014.

[10] B. X. Ren, H. F. Li, W. J. Du, Z. Chen, H. F. Wang, and S. Q. Bu, "Dynamic performance of a vector-current controlled unified power flow controller installed in a real Chinese power network," IET Conf. Publ., vol. 2016, no. CP696, 2016, doi: 10.1049/cp.2016.0469.

[11] A. Jain, L. K. Yadav, A. Omer, and S. Bhullar, "Analysis of Effectiveness of SSSC in Transmission Network using PI Controlled Technique," Energy Procedia, vol. 117, no. July 2019, pp. 699–707, 2017, doi: 10.1016/j.egypro.2017.05.184

IX. APPENDIX

This is the voltage comparison waveform of 132kV buses of the eastern grid after implementing various FACTS devices.