ISBN : 978-99936-986-3-0

# JNEC

## *Thruel Rig Sar Toed*

## འཕྲུལ་རིག་གསར་གཏོད།

Academic Excellence Through Research and Innovation

Volume - III, Issue - I

https://www.jnec.edu.bt

**Editorial Correspondence**: Any inquiries related to Thrue-rig Sar-toed, should be addressed to Ngawang Chogyel, Asst. Research Officer at ngawangchogyel@jnec.edu.bt or Hemlal Bhattarai at hemlal.jnec@rub.edu.bt

**Design and Layout**: Sonam Jamtsho, Head, ITSU, Jigme Namgyel Engineering College,

Royal University of Bhutan

## Foreword

We are here yet again with the third edition (Vol. III) of the "Thrue Rig Sar Toed - academic excellence through research and innovation", a publication of Jigme Namgyel Engineering College (JNEC). Thrue Rig Sar Toed (TRST) is a humble attempt to showcase the scholarly works carried out by students and academics of JNEC in their respective areas of expertise.

It is strongly believed that the purpose of formal education is not only to test one's knowledge and skills through examinations only but also through research outputs vis-à-vis the application of knowledge and skills to benefit the society in general. JNEC has been striving to excel in the area of research and innovation so as to benefit the society and TRST serves as one of the platforms to showcase such scholarly works. The third volume features eight technical papers from different subject areas.

It is my humble request to our esteemed stakeholders to continue to support us and provide constructive criticism and feedback. These will help us grow further and contribute towards meaningful research and innovation in the college, and also instill the importance of research in the minds of our students at an earlier stage of their lives, while this will also serve as a link between the academia and the industry.

My best wishes to the publication team and the contributors with their scholarly endeavors. Please continue to work and make meaningful achievements in your research career.

Tashi Delek!

**Andu Dukpa, PhD**

**(President, JNEC)**

# TABLE OF CONTENT

# 3D Landscaping of Jigme Namgyel Engineering College by 2030

Kezang Choden, Dorji Jamtsho, Harka Bahadur Rai, Novin Thara, Tshewang Pelden , Jigme Tenzin[1]
Department of Civil Engineering and Surveying ,
Jigme Namgyel Engineering College, Royal University of Bhutan, Dewathang, Bhutan

*Email: jigmetenzin@jnec.edu.bt[1]*

***Abstract— Three-Dimensional (3D) modeling is the representation of depth in a two-dimensional image of an object [1] and landscaping is the activities that modifies the visible features of an area of land including living and non-living objects [1], combine together gives a sense of realism. Landscape is important in spatial development for campus space. It will also offer an enormous influence on visual quality, student performance and quality of life [2]. This research work implements the integrated concept of 3D modeling and landscaping. The expected result was obtained with the help of cost-effective software such as LisCAD, AutoCAD, SketchUp and Lumion. 2D map of the campus was created using LisCAD, which was processed in the AutoCAD for generation of contour map. Converting into required file format and imported into SketchUp for modeling the entire campus area with existing 3D structures. JNEC strategic plan 2030 was used to project population until 2030 and analyze the required new structures in the campus both for students and staff. Suitable site locations were identified, modelled into 3D and landscaped. Complete 3D landscape rendering was done in Lumion to enable realistic view of JNEC campus by 2030. These complex 3D landscape models can serve as layouts for updating already existing data in databases and accuracy improvements to 2D maps. It can be reused for future projects which will help to lower the cost of production and gives good visual advantages compare to 2D maps [3].***

***Keywords - Landscaping, Modeling, Rendering, strategic plan, realistic view.***

## 1. INTRODUCTION

In 3D computer graphics, 3D modeling (or three-dimensional modeling) is the process of developing a mathematical representation of any three-dimensional surface of an object (either inanimate or living) [1]. The first 3D models were created in 1960s by the creator of Sketchpad, Ivan Sutherland [4]. The proposed project based on the 3D modelling is "3D landscaping of JNEC by 2030" which focus on creating realistic view of the campus using appropriate data. As landscapes is now mandatory everywhere along the development of mankind and its artifacts. Landscape visualization is one of the important parts of a designer and planner's work [5].

Today, most of the landscape designs are created by architects with the aid of Computer Aided Design (CAD). CAD systems empower architects and builders to imagine, achieve, alter, and elaborate on their ideas until perfection is reached. Landscape architects and planners communicate with specialists and lay people through visual representations. In this way their thoughts about the real world are more concrete [6].

This research was divided into three phases. The first phase was modeling of existing structure followed by second phase consisting of designing new structure and the third phase was landscaping of the modeled structure using sketch up and rendering it using Lumion. It is worth mentioning that 3D modeling is not only for professionals, although the cost for acquiring the hardware and software necessary is still relatively expensive.

### *1.1 Study Area*

The study was carried out at Jigme Namgyel Engineering College, Dewathang gewog under Samdrup Jongkhar Dzongkhag. Jigme Namgyel Engineering College was introduced on 22nd February 1974. The college infrastructure development was already started since 1972. Presently the college

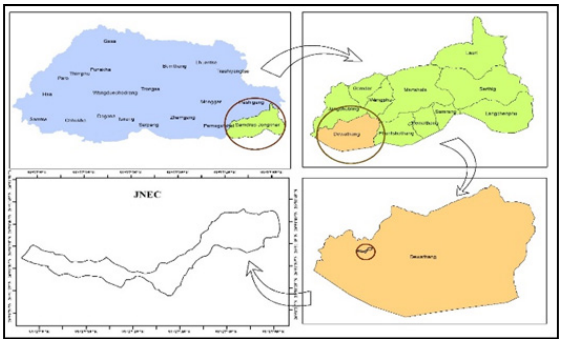



*Fig 1: Study Area*

offers 8 programs, 7 programs in diploma level and 1 program in bachelor level. The Jigme Namgyel Engineering College is one of the of the ten member colleges of the Royal University of Bhutan (RUB) . Study area map is shown in Fig. 1.

## 2. MATERIALS AND METHODOLOGY

Materials are one of the most important equipment for any kind of surveying project [7]. Instrument such as total station, tripod, measuring tape and abney level was used during the project. Every material used hold their own importance. Total station was used to measure horizontal and vertical angles as well as slope distance from a single setup. Instantaneously, components of horizontal and vertical distances, elevations and coordinates were computed. Measuring tape was also used wherever necessary. The tripod was used to provide support to total station, holding it steady so that the person using it can make accurate calculations. Lastly abney level was used to place high precision surveying equipment, particularly in rough terrain.

The overall flow chart of methodology adopted to carry out this project is shown in Fig. 2. Initially started with identification of problem by collecting information and related journals for the project, review literature that supported the project idea and also implementing those. The main field work begins with the site visit and campus verification which included listing of existing infrastructures which need to be modeled in 3D. For the buildings whose plan were not available, alternative methods such as measuring tape and abney level were used to measure length and height of the buildings and spaces. After completion of preliminary survey, available data such as boundary data from NLCS and JNEC Strategic Plan were collected to project student and staff population and analyze the requirement of new structures and facilities within the campus. With data collected on existing number of infrastructures, their existing 2D plan, the infrastructures were

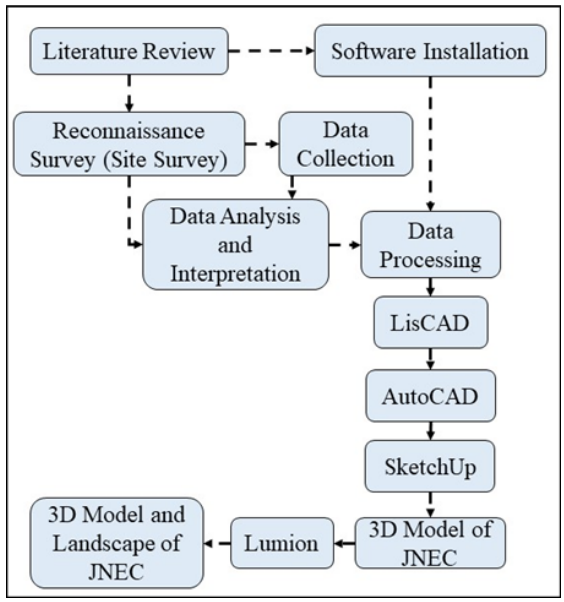



Fig. 2. Flow chart of methodology

modeled into 3D using SketchUp. After completion of modeling of the features, 2D contours were generated in LisCAD, later exported to AutoCAD for smoothing the contours and also for converting the LisCAD file format (.see) into AutoCAD file format (.dwg) to be used in SketchUp software.

The smoothened contours in AutoCAD are exported to SketchUp, where contours are closed, and the bases (building base and road-network base) are stamped and followed by placing the infrastructure exactly on the stamped base. Eventually the landscaping of campus is carried out in SketchUp. The rendering of the modelled infrastructure was done in Lumion to allow models to give realistic visual image with real life environments and striking artistic flair

- Data collection

Data collection is the process of gathering information on targeted variables in an established systematic fashion, which then enables one to answer relevant questions and evaluate outcomes

and necessary details [1]. With the help from the college administration, we were able to get the total number of staff intake and students' intake by 2030 which is shown in Table 1. Fig. 3 shows some of the elevation of existing buildings collected.

*Table 1.Student and staff population statistics by 2030*

| Year | No. of Faculties | No. of Students |
|---|---|---|
| 2019 | 120 | 723 |
| 2020 | 134 | 1167 |
| 2021 | 140 | 1320 |
| 2022 | 142 | 1400 |
| 2023 | 143 | 1430 |
| 2024 | 149 | 1460 |
| 2025 | 155 | 1520 |
| 2026 | 156 | 1580 |
| 2027 | 158 | 1620 |
| 2028 | 158 | 1620 |
| 2029 | 161 | 1620 |
| 2030 | 163 | 1700 |

*Fig 3. Elevation of existing building*

*Data analysis and interpretation*

Fig. 4 and Fig. 5 shows the increasing number of populations in the campus over the years by 2030. The graph clearly depicts that the number of staffs is increasing in the campus which indicates the problem of accommodation over the year and sees the needs to construct residential building

The above graph in Fig. 5 depicts the total number of student intake by 2030. It can be concluded that the number of student intake in every following year will be increasing by certain percent which will lead to the fact that the available space for student's accommodations will not be enough if it's kept same. These calls for the real need to plan for new residential building.

Through data analysis, it can be concluded that the

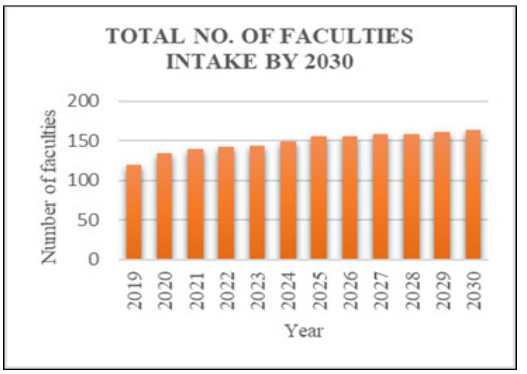



*Fig. 4.Staff statistics by 2030*

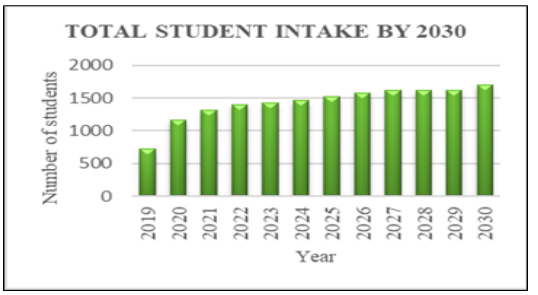



*Fig. 5. Student statistics by 2030*

present accommodation of the whole population will not be enough for the sudden growth of population in the following years due to introduction of new programs. Therefore, to resolve the accommodation issue, we have come up with new residential building plan for both student and staff. Keeping financials and working system of the campus in check, the following interpretation was concluded as shown in Table 2 ((1yr – First year, 2yr – second year, BRD – boarding, SLFC – self catering).

The idea is to prepare a plan for G2+ building for self-catering, whose capacity will be forty-eight numbers of students in a building and two in each room with eight rooms in each floor. Building details is as shown in Table 3 which will cover the area of 300m3.

For boarding students, G3+ building is to be constructed, whose capacity will be two-hundred fifty-six in a building with four students in each room and each floor will have sixteen rooms as shown in Table 4 and the area covered is 585m3.

The new design plan for staff as per the analysis is as shown in Table 5.

*Table 2. No. of rooms required for student hostel*

| | No. of students | | No. of rooms | | Total no. of students |
|---|---|---|---|---|---|
| Year | 1yr | 2yr | BRD | SLFC | |
| 2019 | 416 | 307 | 400 | 144 | 723 |
| 2020 | 590 | 577 | 400 | 144 | 1167 |
| 2021 | 740 | 580 | 464 | 168 | 1320 |
| 2022 | 820 | 580 | 464 | 168 | 1400 |
| 2023 | 850 | 580 | 464 | 168 | 1430 |
| 2024 | 850 | 610 | 464 | 168 | 1460 |
| 2025 | 850 | 670 | 464 | 168 | 1520 |
| 2026 | 910 | 670 | 464 | 192 | 1580 |
| 2027 | 930 | 690 | 464 | 192 | 1620 |
| 2028 | 930 | 690 | 464 | 192 | 1620 |
| 2029 | 930 | 690 | 464 | 192 | 1620 |
| 2030 | 970 | 730 | 464 | 192 | 1700 |

The plans mentioned above can be implemented as

*Table 3 Building details*

| Individual room details | | Floor Details | | | |
|---|---|---|---|---|---|
| Room Size(m) | 6m X 4m | | First | Second | Third |
| Capacity | 2 heads | Total no. ff Rooms | 8 | 8 | 8 |
| No. of washrooms | 6 toilets with 4 bathrooms | Total capacity | 16 | 16 | 16 |

*Table 4 Building details G3+*

| Individual room details | | Floor Details/Rooms | | | |
|---|---|---|---|---|---|
| Room Size(m) | 5m X 5m | First | Second | Third | Fourth |
| Capacity | 4 heads | 16 | 16 | 16 | 16 |
| No. of washrooms | 10 toilets with 6 bathrooms | 64 | 64 | 64 | 64 |

*Table 5. Staff building details*

| Floor | No. of Quarter | Total Floor Size | No. of rooms |
|---|---|---|---|
| First Floor | 4 | 7m X 11.5m | 4 |
| Second Floor | 4 | 7m X 11.5m | 4 |
| Third Floor | 4 | 7m X 11.5m | 4 |

per the five-year plan of the Royal Government of Bhutan.

## 3. RESULTS AND DISCUSSIONS

- Data processing in LisCAD

LisCAD is an innovative and high-quality land surveying and engineering software. We used LisCAD software to create complete topographic

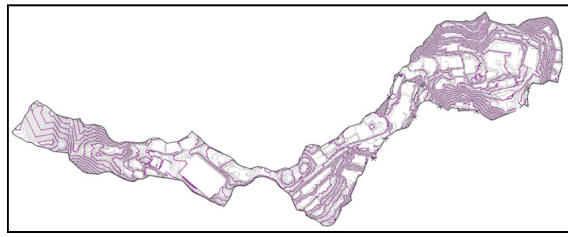


*Fig. 4. Map showing contour generated in LisCAD*

map of the college as topographic maps conveys natural 3D formations in a 2D format and shows how other features match to these formations and used the to generate contours as shown in Fig. 4.

- Data processing in AutoCAD

The AutoCAD software was mainly used for smoothing the contours generated in the LisCAD as shown in Fig. 5.

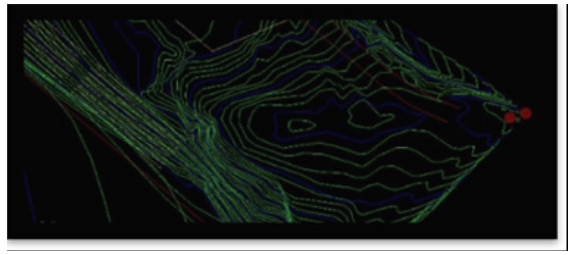


*Fig. 5. Contour smoothening in AutoCAD*

Contour mapping in LisCAD makes the corners and edges sharp, so as to remove those sharp corners and

edges, the smoothing of contours is performed. Since SketchUp cannot read LisCAD file, the contour map generated in LisCAD is exported to AutoCAD so that it can further be exported in to SketchUp.

- Data processing in SketchUp

Most of the data processing was performed using SketchUp, firstly for modeling of the infrastructure and later for landscaping of the whole campus before exporting and rendering in Lumion. The modeling and designing of existing building, new building and others structure such as canopy, water-tank and sport complex (basketball court, volley ball court, soccer field, long tennis) were performed in SketchUp referring to the gathered data and giving exact coloring, giving realist view of campus by 2030.

After completing designing and modeling of the features, the landscaping of campus by 2030 was made easy. The smoothened contours generated in AutoCAD was exported to SketchUp as shown in Fig. 6.

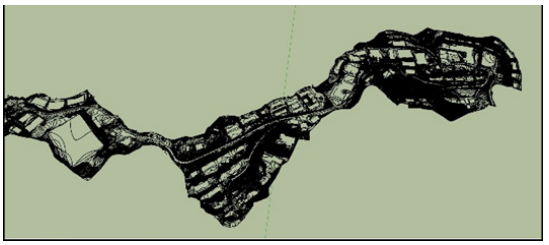


*Fig. 6. Smoothened contour imported from AutoCAD to SketchUp*

After exporting smoothened contours, the contours were closed as shown in Fig. 7 to carry out the landscaping of campus. After closing of the contours, the building base and road network base were stamped on the contour map.

Then after completing with closing of contours and stamping of base, the features were placed on their exact position and eventually complete landscaping of JNEC campus using SketchUp as shown in Fig. 8.

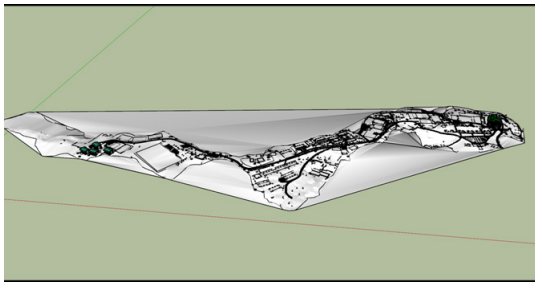


*Fig. 7. Map depicting closed contours with stamped base*

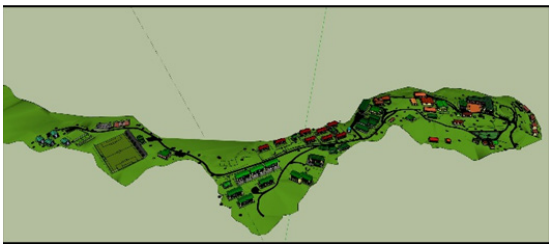


*Fig. 8. Final landscaping in SketchUp*

- Data processing in Lumion 8+

Lumion is software where we can show night and day vision of the campus with landscaping tools. The data processing in Lumion was displayed in two section. First one as 3D modeling and second section as landscaping since these two are different ideas combined to make single concept for the project.

- Result I

It displays degree of closeness that the 3D modeling of infrastructure in realism as depicted in Fig. 9 and Fig. 10.

*Fig. 9. showing day view and night view of area above CS*

- Result II.

Displays the actual landscaping. All those possible changes brought within the campus by 2030, proper usage of empty space and resources, keeping in mind the financial status of the college. As shown in Fig. 11 and Fig. 12.

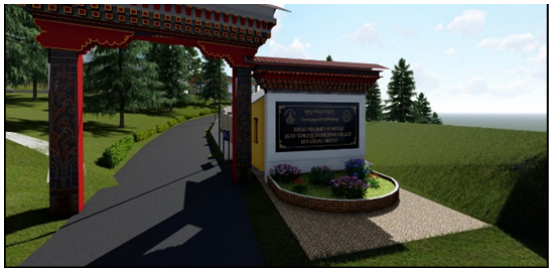


*Fig. 10. Showing day view and night view of entrance of campus*

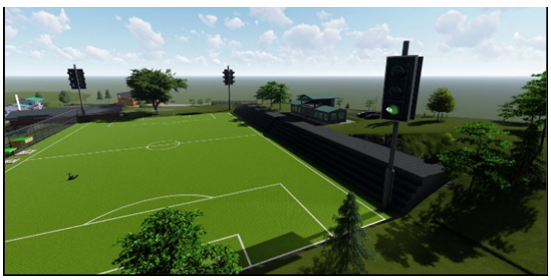


*Fig. 11: showing football ground*

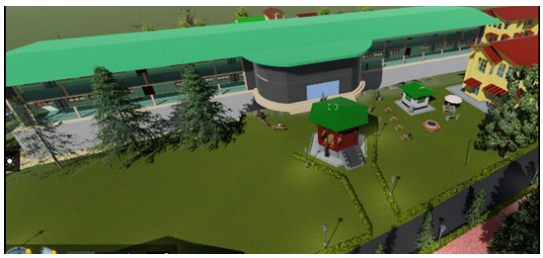


*Fig. 12. showing landscaping in and around academic block*

## 4. CONCLUSION

Landscaping was developed where the necessary natural resources exist and only where there is enough space for development. Topographic data were imported into SketchUp software to generate 3D surface and structures were merged into its location. Then part of landscaping such as exiting plantations, new garden, lawn, open spaces, parks etc. were created. The 3D landscape with output projected until 2030 corresponding to the population growth can be used as a reference map by the college for any construction activities within 2030. It will help in locating suitable site for any construction in line with related adjacent structures. Also, it will give clear idea to convince during budget proposal for any construction with accurate cost estimates. Out of many advantages, 3D view of the site before construction can be seen.

## 5. ACKNOWLEDGMENT

Our project team would like to thank college for rendering us all the necessary support that is required during the course of project and Royal Government of Bhutan for providing us with the scholarships for studies. We would also like to share our gratitude to project guide and faculties of Department of Civil Engineering and Surveying for your feedback and all support in making this project a great success.

## REFERENCES

[1] A. Stevenson, Oxford Dictionary Of English, Great Clarendon street: Oxford university press, 2010.

[2] A. Ender Peker, “Exploring the ways in which campus open space design influences students’ learning experiences,” Landscape Research , 2019.

[3] N. Thomas, E. Erik, L Anders & T. Mikael, “Learning benefits of using 2D versus 3D maps: evidence from a randomized controlled experiment,” Journal of Geography, 2013.

[4] D. Scott-Leslie, “3D Modeling: An Overview of History & Industry Application,” 3D Modeling, 2018.

[5] L. B. Karl, S. B and L. A. M, Fundamentals of Landscape Architecture, united states of america: international textbook company, 1961.

[6] carducci associates, landscape architecture and Planning, californina: adventure work press, 2013

[7] S. J. K. &. M. V. Singh, “Image Basewd 3D Modeling of Campus (Department of Civil Engineering, IIT Roorkee, Uttarakhand, India) by Using SketchUp.,” International Journal of Advanced

Civil Engineering and Architecture Research, 2,( 1),, pp. 65-71., 2013.

[8] N. Jennifer, R. Wolch, “landscape and Urban Planning,” Urban green space, public health, and environmental justice: The challenge of making cities ‘just green enough’ , vol. 125, pp. 234-244, 2014.

# Power Factor Improvement As A Means To Save Electrical Energy

Namgay Thinley, Thinley Norbu, Tshering Pem, Rigzin Lhendup, Thinley Wangchuk, Thinley Tobgay[1]
Department of Electrical Engineering,
Jigme Namgyel Engineering College, Royal University of Bhutan, Dewathang, Bhutan

*Email: thinleytobgay@jnec.edu.bt[1]*

***Abstract*—The need of power factor improvement and the impacts of power factor improvement in electrical system is discussed in this paper. The objective of this project work is to monitor and control the cosine angle between the voltage and the current in power system in order to save the electrical energy. This paper also covers the basic concepts of power factor, cause and effect of low power factor, method to improve the power factor and the advantages of power factor improvement by use of capacitors. The low power factor problem is one of the important issues in electrical industry. This problem reduces the economy index value of Supply Company. This project would be of outmost importance for the industries where heavy inductive loads are inevitable. A simulation work was carried out to observe how power factor variation of capacitance of capacitor. The simulation work is essential to determine the correctness and efficiency of a design, and the merits of alternative designs without building the physical system. The key consideration of this study was to find out the causes of low power factor in the large inductive load that is based on S.D. Eastern Bhutan Ferro Silicon Company and to find out how to improve power factor and save electrical energy.***

***Keywords*— Active Power, Apparent power, Capacitor bank, electrical loads, lagging power factor, leading power factor, unity power factor.***

## 1. INTRODUCTION

In the recent years, an increasing attention has been paid to minimize the cost of energy and inefficiency in electricity generation, transmission, and distribution system. The cost of energy mainly depends on total energy consumed and the power factor. Power factor is defined as the ratio of true power that is used to do useful work to the total power supplied to the system. The power factor varies differently with the different electrical loads. Generally, the resistive type of loads has power factor near unity whereas the capacitive type of load has leading power factor. The inductive loads which are basically used in the industries, such as induction motors, transformers, and furnaces have low power factor. Low power factors are not just caused by inductive loads but also by variation in system loading and harmonic currents. Some of the low power factor impacts include voltage drop, power loss in transmission line and in consumer side, requires high rating switchgear and high energy bill [1].

As an electrical engineer, it is important to get oneself educated about the impacts of low power factor and take necessary actions in reducing these impacts. Some of the methods to improve power factor includes using of capacitor, phase advancers and synchronous condensers.

## 2. PROBLEM STATEMENT

- In an electric power system, a load with a low power factor draws more current than a load with a high-power factor for the same amount of useful power transferred [1]. The higher currents increase the energy lost in the distribution system and require larger wires and other high rated equipment.
- Some of the major problems related to low power factor are as follows:
- Requires larger kVA rated equipment which are cost intensive.
- Higher copper loss due to high current drawn at low power factor.
- Greater conductor size caused due to I2R loss.
- Poor voltage regulation due to large voltage drop in the equipment.
- High demand charges/kVA.

- Reduced efficiency of the system.

## 3. METHODOLOGY

With an aim to study the impacts of electrical loads on power factor and to analyze the various impact of having undesired power factor (i.e. less than unity), some of the problems related to low power factor in the system were discussed. The research papers published by various authors around the globe on the similar topic is reviewed so that our methodology

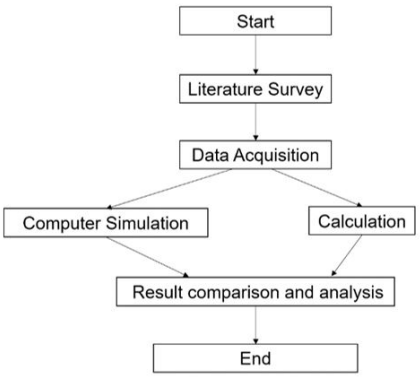



*Figure 2 Methodology flow Chart*

can be compared to obtain an optimum comparison. Following this, planning about how to go about the study and the research on this very topic were discussed as in figure 2. We studied about different types of electrical loads in which the resistive load has unity power factor and it does not have much impact on the distributor and the consumers. Whereas the capacitive load has leading power factor and the inductive load have lagging power factor and causes negative impacts on consumer as well as to distributor. In order to overcome these problems in the electrical system, there are various methods to improve low power factor. Some of the methods include using of phase advancer, synchronous condenser and shunt capacitor. The advantages of using these power factor improving methods are, it will maximize the current carrying capacity, improve voltage to equipment, reduce power losses, and lower electric bills and it will improve power factor.

Since the comparative study is based on S.D. Eastern Bhutan Ferro Silicon Factory, required data from the factory for the study and research were collected. The variation in power factor for different electrical loads and its improvement by use of shunt capacitor was determined by using MATLAB/ Simulink software package. The result obtained from the simulation was compared with the calculated values and the unsatisfactory result were solved by rechecking with the calculated values. From the various methods of power factor improvement, the S.D. Eastern Bhutan Ferro Silicon Factory uses shunt capacitors and the problems related to low power factor are solved with the improvement of power factor. Some of the merits gained from good power factor are that it reduces the kVA rating of the equipment, draws low current reducing the copper loss and the conductor size, improved voltage regulation and the efficiency of the system, and the reduced kVA charges. Not only the charges but also energy is saved by connecting the shunt capacitor in the system.

## 4. RESULT AND ANALYSIS

In this project, a selection of performance parameter has been done of shunt capacitor to improve the power factor. For this purpose, at first no capacitor is connected in the S.D. Eastern Bhutan Ferro Silicon Factory equivalent Simulink model and simulate

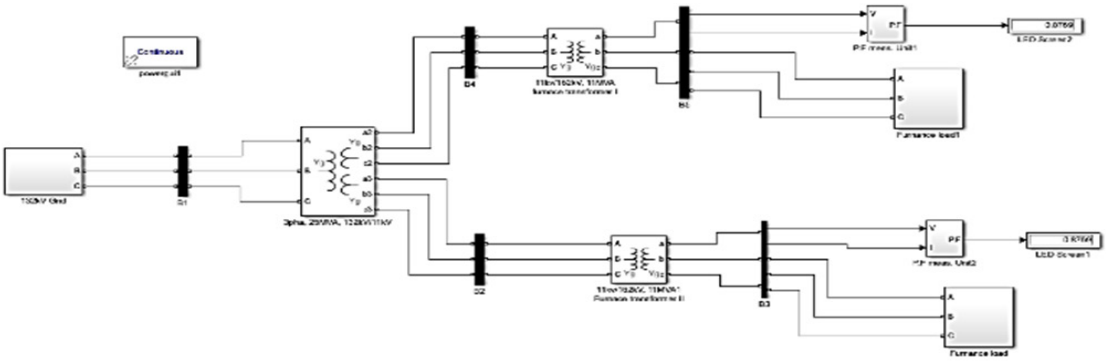


*Figure 1 Simulink model without Capacitor*

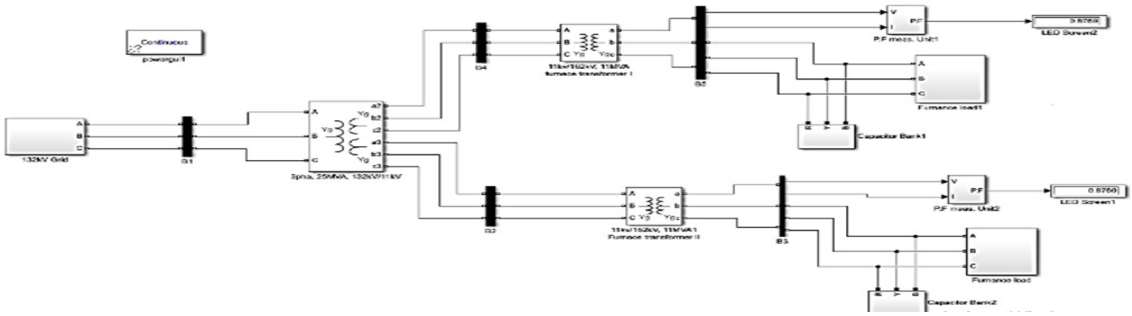


*Figure 3: VI wave without capacitor*

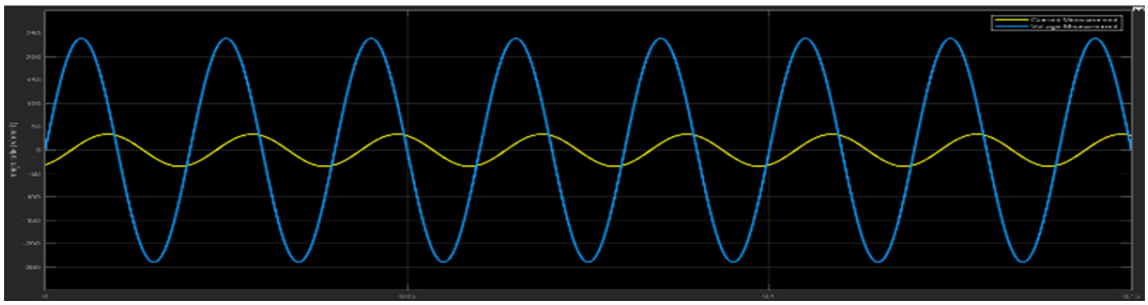


*Figure 4: MATLAB Simulink with capacitor*

the initial power factor. The Simulink model for determining the power factor without the capacitor and its wave form are as shown in figure 1 and figure 4.

The waveform in figure 4 shows that the current is lagging the voltage by certain angle and the power factor is low (0.5668 lagging).

In the next Simulink model, a shunt capacitor is connected to see the power factor improvement. The Simulink model and the VI waveforms are shown in figure 3 and figure 6.

The diagram in figure 6 shows the waveform of current and voltage when the power factor correcting capacitor is connected parallel to the load. The phase angle between current and voltage is almost zero and power factor is improved which is almost equal to unity.

From these two waveforms, it is found that for cFrom these two waveforms, it is observed that for circuit having low power factor draws high current compared to circuit with higher power factor. The in figure 1 had initial power factor of 0.5668 lag and this low power factor can be improved by connecting capacitor parallel with circuit load. The wave form of two circuit shows that current drawn from the source is maximum for circuit without capacitor and the current decreases when power factor is improved by connecting capacitor parallel to the load.

$$Z = R + jX \quad (1)$$

$$X_L = 2\pi fL \quad (2)$$

$$I = V/Z \quad (3)$$

$$S = VA \quad (4)$$

$$P = VI \cos\emptyset \quad (5)$$

$$\text{Reactive power} = \sqrt{S^2 - P^2} \quad (6)$$

For unity P.F

$$Q_c = Q_L \quad (7)$$

$$C = \frac{Qc}{2\pi fV^2}\ \mu F \quad (8)$$

The capacitor to be connected in the circuit can be calculated employing following equations [1]:

*4.1 Power factor vs. capacitance*

The graph in figure 5 shows that low power factor can be corrected optimally by using the right capacitance value of shunt capacitor. The power factor increases with increase in capacitance of shunt capacitor up to its maximum value that is unity and on further increasing the capacitance of the shunt capacitor power factor decrease. Taking this observation, the capacitor value must be selected carefully to achieve power factor improvement.

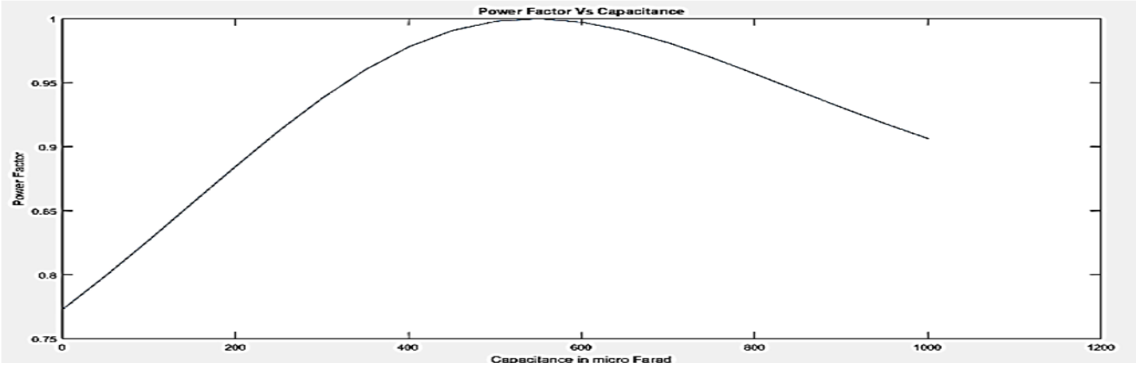



*Figure 5 Capacitance vs Power factor curve*

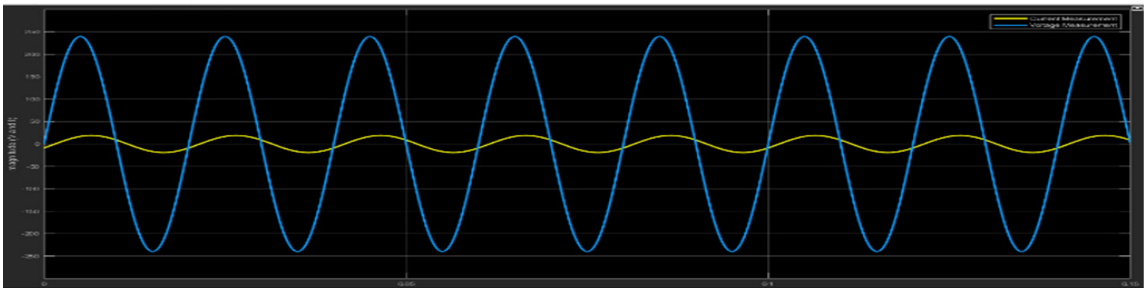


*Figure 6 VI waveform with Capacitor connected*

### *4.2 Cost analysis for furnace energy consumption*

Our team performed calculation on how much energy is saved when a correct capacitor is connected in S.D Eastern Ferro Silicon Factory. The calculation is as shown in table 1. With capacitor connected the S.D Eastern Ferro Silicon Factory can save up to Nu. 10,577.29 per day. With this rate of saving the monthly saving of the company will be Nu. 317,318.7.

Table no. 1: Billing for furnace

| Type of Charge | Cost (Nu.) without capacitor Bank | Cost (Nu.) with Capacitor bank |
|---|---|---|
| Energy charge (Nu. / kWh) | 274752 | 270936 |
| Demand charge (Nu. /KVA) | 76064.52 | 69303.23 |
| Total Bill (Nu.) | 350816.52 | 340239.23 |
| Total amount saved=Nu10577.29/day | | |

## 5. CONCLUSION

Poor power factor means more apparent power being drawn because of high reactive power requirement due to the inductive loads in the industries. Therefore, in order to reduce the apparent power drawn; one method is to connect capacitor and improve the power factor in order to reduce the electricity bill. These kind of studies gives an operator the trends of electrical parameter in the industries and enable to take next step in installation of reactive compensator if necessary. Therefore, the required reactive power to compensate reactive power drawn by load can be calculated based on power factor and real power, which ultimately helps to compute the rating of capacitor banks for improvement of power factor to a desired value.

This study shows that installation of capacitor banks in industries are very effective and saves significant amount of cost resulting from electrical energy consumption. MATLAB Simulink model was developed and simulation carried out to validate the power factor correction for case study and satisfactory result obtained.

REFERENCE

[1] C.L Wadhwa, Electrical Power System, ND Hatziargyriou, 1995.

[2] E.Dieter, "Quora," Electrical Engineering at ETH Zurich, 21 3 2019. [Online]. Available: https://www.quora.com>what is reactive power?/. [Accessed 23 2 2019].

[3] G. B.R, "Generation of Electrical Energy," Technology and Engineering, 12 3 2017. [Online]. Available: https://books.google.bt>books/. [Accessed 4 3 2019].

[4] G.jonathan, "jonathan Gracey," 13 2 2016. [Online]. Available: https://www.google.com>powertriangle/. [Accessed 9 3 2019].

[5] O.Rick, "electrical dataloggers," acksen>, 4 1 2019. [Online]. Available: http://www.ele.com;powerfactor;correction/. [Accessed 12 03 2019]. ctrocorder

[6] R. &. D.N.Vishwakarma, Power System Protection And Switch Gear, TaTa McGraw-Hill Education, 2001.

[7] V. M. a. R. Metha, Basic Electrical Engineering, Ram Nagar, New Delhi: S. Chand and Company Ltd., 2012.

[8] Rajput, "umang Rajput," instant solution, 12 3 2018. [Online]. Available: https://youtu.be/CpMIRQRih TM. [Accessed 12 3 2019].

# Spatial and temporal trend analysis of rainfall in Bhutan

Phuntsho[1], Sher Bdr. Ghalley[2], Sonam Wangchuk[3], Tashi Wangchuk[4], Tshering Choden, Vasker Sharma[5]
Department of Civil Engineering and Surveying,
Jigme Namgyel Engineering College, Royal University of Bhutan, Dewathang, Bhutan

*Email: phuntsho.8.wangdue@gmail.com[1], sherghaley@gmail.com[2], sonambrookwangchukt@gmail.com[3], wangchuktashi375@gmail.com[4], vaskersharma@jnec.edu.bt[5]*

***Abstract— Seasonal and annual rainfall series was prepared from the daily rainfall data collected from twenty class A meteorological stations located in each districts of Bhutan. The seasonal and annual rainfall data was analyzed for three altitude zones for finding the spatial and temporal trend over the study period (1986-2017).For trend analysis, a non-parametric Mann Kendell (MK) test was applied in seasonal and annual data series of all the twenty stations. Sen's slope test was applied for finding the magnitude of the trend. Additionally, Modified Mann-Kendell (MMK) test method is used to eliminate the effect of serial correlation on the Man Kendell test result. In the higher altitude zone, Chamkhar station under Bumthang district located at the altitude of 2470 meter shows the significant increasing trend+2.72 (2.4mm/year) magnitude in pre-monsoon season. Paro station located at the altitude of 2406 meter shows a significant decreasing trend -2.25(-3.2mm/year) in monsoon season. Gasa station located at the altitude of 2760 meter shows a significant decreasing trend of -2.38 (-0.9mm/ year) magnitude in winter. In the middle zone, Tangmachu station under Lhuntse district located at the altitude of 1750 meter shows a significant increasing trend +2.82 (2.9mm/year) in pre monsoon season and also shows a significant decreasing trend -3.39 (5.5mm/year) in monsoon season. Zhemgang, Punakha, Kanglung, Dagana shows significant decreasing trend of -2.51(-1.1mm/ year), -3.28(-0.8mm/year),-2.77(-1.1mm/year) and -2.51 (-1.2mm/year) respectively in Winter season. Pemagatshel station located at the altitude of 1648 meter shows a significant decreasing trend -2.09(-8.9mm/year) magnitude in annual. Damphu station under Tsirang district located at an altitude of 1520m shows a significant decreasing trend -2.84 (-10.1mm/year), -2.03(-1.0mm/year) and -2.66(-4.1mm/year) in annual, winter and pre monsoon season respectively. Kanglung station also shows a significant decreasing trend -1.99(-4.5mm/year) and -2.12(-4.1mm/year) in annual and monsoon season respectively. In the lower zone, Deothang station under SamdrupJongkhar district located at the altitude of 800 meter, Phuntsholing station under Chhukha district located at the altitude of 220 meter and Sibsoo station under Samtse district located at the altitude of 550 meter shows decreasing trend -2.51 (-2.8mm/year), -2.34 (-4.8mm/year) and -2.81(-2.0mm/year) magnitude respectively in winter season. Sibsoo station located at the altitude of 550 meter shows a significant increasing trend +2.19(23.0mm/year) magnitude in monsoon season. Bhur station under Sarpang district located at the altitude of 375 m shows significant decreasing trend -2.97(-8.3mm/year) and -2.64(-5.7mm/year) in pre monsoon and post monsoon season respectively. Phuntsholing station also shows significant decreasing trend -2.66(-2.5mm/year) in pre monsoon season.***

## 1. INTRODUCTION

Ongoing climate changes are likely to have considerable negative consequences for livelihoods in many developing countries because in future climate is expected to become more extreme and variable. Any changes in climate with respect to onset, duration, and intensity of the rainy season would therefore severely affect both society and ecosystems in terms of direct impact on agriculture, hydropower, forest management, and conservation and indirect impact on health, education, and security. Rainfall is one of the key climatic variables that affect both the spatial and temporal patterns of water availability. One of the challenges faced in climate change is identification and quantification

of rainfall trend. Bhutan is part of the Himalayan global biodiversity located at an elevation ranging from 100-7550m which is associated with extreme variation in climatic conditions even across relatively small areas, therefore Bhutan is susceptible to high climatic variations in future and such variation in climate specially rainfall will influence the capacity of agriculture and hydropower generation as it is directly dependent on the availability of the rain water. Monthly rainfall in three altitude zones as per the study done by [1] are ; higher altitude zone(2000m-3000m) is between 0-280mm whereas in the middle altitude zone (1000m-2000m) is between 50mm-900mm and in the lower altitude zone (<1000m) is between 80mm-1360mm), the above result clearly shows that the lower altitude zone located in the southern region of the country receives high monthly precipitation followed by the middle altitude zone located in the central region of the country while the higher altitude zone located in the northern region receives less amount of monthly precipitation compared to lower and middle altitude zone.

Bhutan's economy is highly dependent on agriculture accounting for 79 percentage of people's livelihoods and hydroelectric power constitutes about 45 percentage of the national government's revenue thus making significant contribution to gross domestic product. A feasible potential for global hydropower is two to three times higher than the current generation, however there is an uncertainty due to climate change causing risk for the hydropower generation sector as the water for the generation of electricity in the hydro power plant are directly collected from the running rivers. Bhutan's hydropower debt is 80 percentage of external debt of ngultrum 184 billion. Therefore, hydroelectric energy is readily available during the monsoon season when the water in the running rivers are available and the hydroelectric energy generation is less during non-monsoon season when the water level in the running river decreases, particularly in winter when demand is high and supply is constant. As the variation in the rainfall influences the generation of hydroelectric power, therefore it is very crucial to understand the spatial and temporal trend of rainfall variation in Bhutan through the work and efforts of research and study. Understanding the trend of rainfall variation will assist in planning and carrying out the feasibility study on hydroelectric power generation and also boost the quality and assist the practice of agriculture, thereby creating employment opportunities for the people of Bhutan.

Thus, the unpredictable weather condition with increasing or decreasing variation in the frequency, intensity and timing of monsoon affects the agriculture production and power generation from hydro power plant, hence the agriculture and hydro power sectors are significantly dependent on the rainfall intensity and other climatic variables. Despite the sensitive respond to climate changes, knowledge of crucial climate variables such as temperature, rainfall and information on how climatic factors affect agriculture, forestry and ecosystems is limited in Bhutan. Moreover, only 0.5 percent of budget is allocated for research therefore, there is lack of specific research agenda to address the effects of climate change. However, such information is needed as a baseline to explore how global climatic changes and its impact on natural, managed ecosystems and human livelihoods in Bhutan. Therefore, understanding the increasing or decreasing trend of precipitation in different altitudinal zones of Bhutan is crucial in widening the knowledge and understanding about the rainfall and other climatic variation pattern.

This study aims in analyzing the spatial and temporal trend of rainfall in Bhutan. Rainfall is one of the important climatic variables that determines the success and failure of agriculture and the hydroelectric power generation. Since the running river is main source of water for power generation in hydropower project and also the running river water is the main source of water supply for irrigation in Bhutan, therefore it is crucial to analyze the rainfall variation trend to widen the knowledge about the future rainfall variation. Spatial Variation of Temperature and Precipitation in Bhutan and Links to Vegetation and Land Cover, and from the study they concluded that the variation of temperature and rainfall across Bhutan may be highest in the world despite its small geographical area and also they have found out that Bhutan receives both summer and winter monsoon rainfall with a strong quadratic relationship with latitude within a 10 range

[2]. Most rainfall occurs in the south and on south-facing slopes during the summer monsoon and in the north and on north-facing slopes during the winter monsoon season. Consequently, east, west, and central Bhutan remain drier throughout the year than the southern and northern regions. In the similar case [3] carried out the study on zonal analysis of climatic conditions in Bhutan and found the precipitation received in all the three altitude zones during the winter months and the highest monthly precipitation during the rainy season in the higher, middle and lower zones respectively. The study also concluded that the western part of the country received much higher precipitation than the eastern parts. There was also significant differences in the climatic conditions of the northern and southern parts as well as those of the eastern and the westerns parts of Bhutan and also provided an understanding about the variations in the climate condition over space and time in Bhutan.

The study carried out on the Precipitation fluctuation in the Nepal Himalaya and its relationship with some large-scale climatological parameters and found that there was a strong relationship between the EI Nino southern oscillation (ENSO) and precipitation fluctuation in Nepal [4]. The correlation was strong between all Nepal monsoon precipitation and SOI averaged over seasons following the monsoon compared with seasons preceding the monsoon season, and in the study done on the seasonal and annual rainfall trend in Himachal Pradesh during 1951 to 2005, the study concluded that the contribution of monsoon rainfall for the lower south-west part of the state is in the range of 60 to 80% of the annual total rainfall, while it is only around 35% for the higher elevation stations in the northern parts of the state and it is also concluded that there is a decreasing trend of spatial pattern of monsoon and seasonal rainfall in the study area [5]. Further the study on the long term spatial and temporal trends on annual and seasonal scales in Wainganga river basin located in Central India, from this study they have found that there was a decreasing trend during the study period of 1901 to 2012 and over all, the study showed the 8.45% of rainfall decreased over the study period [6] but in the another study on the seasonal rainfall trend in India, from the study they found that there was some changes in the trend of rainfall of the rainy months, negative trend for June and September, but for July and August positive trend was observed over the study area [7]. The Indian monsoon rainfall variability in global warming scenario and found that there was no clear role of global warming in the variability of monsoon rainfall over the study period from 1871 to 2001, global warming was not the major factor that leads to the rainfall variation [8].

In the Indian Himalaya the study carried out the Analysis of historical changes in rainfall in the Indian Himalayas and from the study they have found out that most probable year of change in annual as well as monsoon rainfall in the region was 1964 [9]. There was an increasing trend up to 1964 (corroborating with all India and nearby plains), followed by a decreasing trend in 1965–1980 (excluding all India and nearby plains). In the entire region, changes were most conspicuous over the Shivaliks region and in the southern part of the Lesser Himalayas. However the study on trend analysis of weather parameters and people perception in kullu district of western Himalaya and from the study they have found the significant variations for minimum temperature, relative humidity and rainfall over the study area [10]. Further, no significant variation was found for maximum temperature which means there was not much variation in maximum temperature due to high variation of rainfall, variation in rainfall maintain the optimum temperature, they have also found that in general perception of the people about the climate change in the study area, climate change is affecting significantly the production of crops, soil, natural resources and vegetation etc. In fact peoples were worried about the changes in weather parameters which had adverse effect on crop yields.

The study on a modified MK test for auto correlated data, they discussed the effect of autocorrelation on the variance of Mann-Kendell trend statistic and the theoretical relationship was derived to calculate the variance of the Mann-Kendell test for auto correlated data and further the study also concluded that the non-parametric MMK trend test is suitable for auto correlated data and the accuracy of the modified Mann-Kendell test in terms of its empirical significance level was found to be superior to that of the original Mann-Kendall trend test in determining the trend [11]. On the other hand the study on use of the standard normal homogeneity test to detect homogeneities in climatic time series and from the

study they concluded that the SNHT is not applicable in detecting breaks located at the beginning and at the end of the series [12].

## 2. STUDY AREA

Bhutan lies between India and China in south Asia. Bhutan is a mountainous country; it lies at the latitude of 27º30'N and longitude of 90º30'E. The altitude

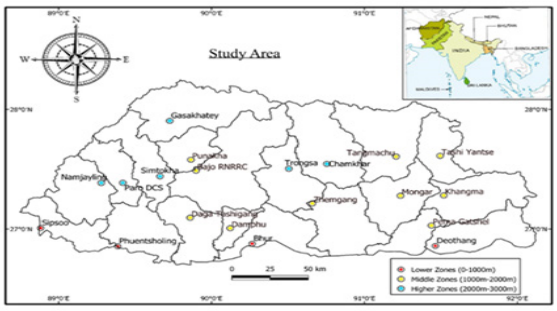



*Fig. 1. Location of Meteorology Class A Station*

ranges from less than 100 m in the southern foothill to about 7550 m in the higher northern region [1].

The study area covers the total area of 38,394 km², there are twenty districts (Dzongkhags) and the Meteorological Stations were located in each of these districts which means that the rainfall data for this study was collected from twenty meteorological stations located at each district of the country. In total there are ninety two Meteorological Stations located across the study area including the Automated Weather Stations (AWS). These Meteorological Stations are broadly classified into three main types on the basis of parameters collected and the type of equipment used. There are Twenty Class A meteorological stations which are located in each districts of the country. The parameters recorded in the class A meteorological Station are: Maximum and Minimum Temperature, Rainfall, Relative Humidity, Wind speed and direction, Sunshine in hours, Solar radiations and Soil temperature. There are sixty one class C meteorological stations which are located across the country while the parameters measured in Class C meteorological stations are: Maximum and Minimum Temperature, Rainfall and Relative Humidity,

In this study Rainfall data from 20 class A Meteorological Stations located in each district is used to analyze Spatial and Temporal trend of Rainfall in Bhutan. The Meteorological Stations were located at a highly varying altitude, since the area is highly mountainous. The Station located at lowest altitude of 220 meter above sea level was at Phuentsholing district which is located at the south-west region of the country and the Station at highest altitude of 2760 meter was located at the Gasa district in the northern region. In this study the meteorological stations were categorized on the basis of attitude as shown is Table 1. There are six stations located at the higher altitude zone, ten stations located at the middle altitude zone and four stations located at the lower altitude zone.

## 3. METHODOLOGY

The rainfall data series of twenty class A stations and sixty-two Class C station were collected from National Center for Hydrology and Meteorology (NCHM), Thimphu. The data set of 20 class A station from 1986-2017 and Class C station from 1986 to 2006 stations was used in this study. The trend was assessed for pre-monsoon (March-May), Monsoon (June-September), post-monsoon (October-November), winter (December-February) and annual for all stations. To test the rainfall trend, a non-parametric test called Mann-Kendell test is applied.

Further Sen's slope test is also used to determine the magnitude of the trend. To detect the autocorrelation in the time series data, Modified Mann-Kendell test is applied to detect the significant change point that exist in the series.

Missing data present various problems in the analysis. First, the absence of data reduces statistical power, which means that there is high chance of

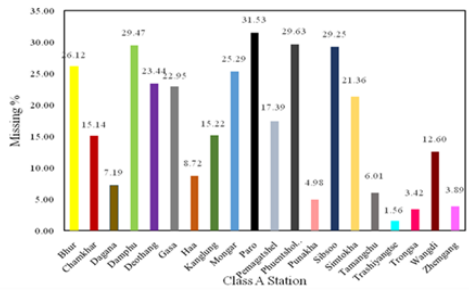



*Fig.2. annual data missing in percentage in all the stations.*

drawing the wrong or unrealistic conclusion from the analysis. Second, the lost data can cause bias in the estimation of parameters. Third, it can reduce the representativeness of the samples. Fourth, it may complicate the analysis of the study. The presence of missing data in the time series can not only lead to invalid conclusion but also make the analysis process difficult [13]. There was missing gap of the data obtained from the National Centre for Hydrology and Meteorology (NCHM), Thimphu for this study. The missing data was observed mostly between the periods 1986 to 1995 for all the twenty stations. The following figure (Fig.2) shows the annual data missing in percentage percentage in all the stations.

*Filling up Missing Values*

In this study, rainfall station consisting more than 10 percent missing data has been discarded and new data value was estimated using Homogenization technique for those months. Effort was made to fill all the missing data by homogenization technique, wherein the stations falling in the homogenous climatic network was considered for computation of the missing data.

## 4. DATA ANALYSIS

### *4.1 Mann-Kendell test*

The Mann-Kendall test is a non-parametric test for identifying trends in time series data. The test compares the relative magnitudes of sample data rather than the data values themselves. Man Kendell test is a non-parametric test that requires only independent time series data for analysis not the normally distributed data in a time series. Non-parametric Mann Kendell test is applied to time series 1986 to 2017 for the Rainfall data obtained from 20 meteorological stations located in twenty districts of Bhutan to identify the trend. Mann Kendell statistic(S) is calculated to find out the increasing, decreasing or no trend in the 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 will be positive (increasing trend). If the earlier value in the time series is less than the later value, value of S will be negative (decreasing trend) and if the value of S is 0 (no trend) in the time series. The value of S is calculated as:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k) \quad (1)$$

$$\operatorname{sgn}(x_j - x_k) = \begin{cases} +1 & \text{if } (x_j - x_k) > 0 \\ 0 & \text{if } (x_j - x_k) = 0 \\ -1 & \text{if } (x_j - x_k) < 0 \end{cases} \quad (2$$

Where:

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 sample size n is calculated as:

$$V(S) = \frac{n(n-1)(2n+5) + \sum_{i=1}^{n} t_i(i-1)(2i+5)}{18} \quad (3)$$

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.

$$\text{Tie correction} = \sum_{i=1}^{n} t_i(i)(i-1)(2i+5) \quad (4)$$

where n is the number of tied groups and ti is the size of the ith tied group. The standardized test statistic Z is computed by:

$$Z_{MK} = \begin{cases} \frac{s-1}{\sqrt{V(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{s+1}{\sqrt{V(S)}} & \text{if } S < 0 \end{cases} \quad (5)$$

### *4.2 Sen's Slope test*

It is necessary to perform Sen's slope estimator test in order to predict the magnitude of the trend. Mann Kendell test compute 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 magnitude of the trend is predicted by the Sen.'s estimator. Here, the slope (Ti) of all data pairs is computed.

$$Q_i = (x_j - x_k)/(j-k) \quad \text{for } i = 1, \ldots\ldots N \tag{6}$$

Where xj and xk are data values at times j and k (j > k), respectively. The median of these N values of Qi is Sen's estimator of slope.

*4.3 Modified Mann-Kendell test*

Mann-Kendall test is that the data are independent and randomly ordered. However, the existence of positive autocorrelation in the data increases the probability of detecting trends when actually none exist, and vice versa [13,14]. The present of autocorrelation in the time series data will increase or decrease the probability of detecting the trend, if there is autocorrelation Mann Kendell test will present the trend of the time series data even though there is no trend in reality. Mann Kendell test will not specify the trend because of autocorrelation or not, the test will merely present the trend of the time series data. Therefore, it is necessary to perform the Modified Mann Kendell test to detect the present of autocorrelation in the time series data and find out the correct trend. The accuracy of the modified Mann Kendell test in terms of its empirical significance level was found to be superior to that of the original Mann-Kendall trend test without any loss of power [7].

Student's t test for autocorrelation, where the test statistic t has student's t-distribution with (n-2) degree of freedom.

The autocorrelation coefficient ρk of a discrete time series for lag-k is estimated as:

$$\rho_k = \frac{\sum_{t=1}^{n-k}(x_t - y_t)(x_{t+k} - y_{t+k})}{\left[\sum_{t=1}^{n-k}(x_t - y_t)^2 \times \sum_{t=1}^{n-k}(x_{t+k} - y_{t+k})^2\right]^{1/2}} \tag{7}$$

The hypothesis of serial independence is then tested by the lag-1 autocorrelation coefficient as H0 : ρ1 = 0 against H1 : |ρ1| > 0 using

$$t = |\rho_1| \sqrt{\frac{n-2}{1-\rho_1^2}} \tag{8}$$

Where the test statistic t has a student's t-distribution with degrees of freedom. If $|t| \geq t_{\alpha/2}$ the null hypothesis about the serial independence is rejected at significance level α, which means there is autocorrelation in the data series.

$$\frac{n}{n_s^*} = 1 + \frac{2}{n(n-1)(n-2)} \times \sum_{k=1}^{n-1}(n-k)(n-k-1)(n-k-2)\rho_k \tag{9}$$

Where n is the actual number of observations, $n_s^*$ is considered as an effective number of observations to account for the autocorrelation in the data and $\rho_k$ is the autocorrelation function of the ranks of the observations. The corrected variance is then computed as:

$$V^*(S) = V(S) \times n_s^* \tag{10}$$

The standard test statistic for Modified Mann-Kendell test ($Z_{MMK}$) is then calculated as:

## 5. RESULT AND CONCLUSION

$$Z_{MMK} = \begin{cases} \dfrac{s-1}{\sqrt{V^*(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \dfrac{s+1}{\sqrt{V^*(S)}} & if\ S < 0 \end{cases} \tag{11}$$

In the higher altitude zone, Chamkhar station under Bumthang district located at the altitude of 2470 meter shows the significant increasing trend +2.72 (2.4mm/year) magnitude in pre-monsoon season. Paro station located at the altitude of 2406 meter shows a significant decreasing trend -2.25(-3.2mm/ year) in monsoon season. Gasa station located at the altitude of 2760 meter shows a significant decreasing trend of -2.38 (-0.9mm/ year) magnitude in winter.

In the middle zone, Tangmachu station under Lhuntse district located at the altitude of 1750 meter shows a significant increasing trend +2.82 (2.9mm/ year) in pre monsoon season and also shows a significant decreasing trend -3.39 (5.5mm/year) in monsoon season. Zhemgang, Punakha, Kanglung, Dagana shows significant decreasing trend of -2.51

| Station Name | Annual | | Winter | | Pre-Monsoon | | Monsoon | | Post-Monsoon | |
|---|---|---|---|---|---|---|---|---|---|---|
| Class A | Z-value | % change | Z-value | % change | Z-value | % change | Z-value | % change | z-value | % change |
| Chamkhar | -0.02 | 0.00 | -0.78 | -13.87 | 2.72 | 44.74 | -2.16 | -14.38 | 0.50 | 1.09 |
| Gasa | **-1.89** | -25.00 | -2.38 | -38.91 | **-2.09** | -3.78 | **-1.78** | -9.47 | -1.56 | -22.26 |
| Haa | -0.60 | -1.18 | -0.81 | -12.34 | 0.83 | 7.58 | -1.15 | -7.70 | 0.10 | 0.00 |
| Paro | -1.31 | -14.81 | -0.46 | 0.00 | 0.76 | 5.05 | -2.25 | -22.50 | -0.50 | 0.00 |
| Simtokha | -1.28 | -13.19 | -1.41 | -31.34 | 0.08 | 0.00 | -1.93 | -24.89 | -0.34 | 0.00 |
| Trongsa | **1.11** | 11.46 | -1.77 | -49.00 | 1.28 | 13.41 | **0.27** | 0.00 | 0.92 | 18.81 |
| Dagana | **-0.93** | -12.89 | -2.51 | -68.47 | -1.61 | -31.35 | **-0.87** | -4.55 | -0.21 | 0.00 |
| Damphu | -2.84 | -23.93 | **-2.33** | -89.24 | -2.66 | -49.98 | -1.12 | -7.07 | -1.67 | -52.32 |
| Kanglung | -1.99 | -18.36 | -2.77 | -78.51 | 0.41 | 0.00 | -2.12 | -16.45 | -0.58 | -1.24 |
| Mongar | -0.76 | -2.30 | -2.22 | -83.76 | -0.55 | -0.29 | -0.70 | -3.57 | 0.18 | 0.00 |
| Pemagatshel | -2.09 | -22.42 | **-2.15** | -65.93 | -1.86 | -19.40 | -1.70 | -12.52 | **-1.77** | -61.12 |
| Punakha | -1.09 | -13.68 | -3.28 | -68.85 | 0.44 | 0.00 | -1.70 | -15.86 | -0.50 | 0.00 |
| Tamangchu | -0.99 | -6.63 | -0.11 | 0.00 | 2.82 | 43.58 | -3.39 | -30.82 | 0.11 | 0.00 |
| Trashiyangtse | -0.66 | -2.37 | -1.22 | -27.18 | 1.61 | 21.58 | -1.52 | -10.02 | -0.45 | 0.00 |
| Wangdi | -0.05 | 0.00 | -1.62 | -42.95 | 0.86 | 7.45 | -0.57 | -0.50 | 0.42 | 0.00 |
| Zhemgang | -0.99 | -3.85 | -2.51 | -77.92 | 0.63 | 0.86 | -0.99 | -5.61 | -0.02 | 0.00 |
| Bhur | -0.41 | 0.00 | **-2.71** | -84.84 | -2.97 | -33.14 | 1.22 | 5.85 | -2.64 | -73.07 |
| Deothang | -0.34 | 0.00 | **-3.38** | -111.86 | -0.79 | -5.97 | 0.41 | 0.00 | -1.25 | -22.61 |
| Phuntsholing | -1.90 | -26.33 | **-2.85** | -149.98 | -2.66 | -55.15 | -0.67 | -1.16 | -1.90 | -41.06 |
| Sibsoo | 1.86 | 19.99 | -2.81 | -80.00 | 1.12 | 11.19 | 2.19 | 19.38 | -1.15 | -17.42 |

*Table 1. MK/MMK test result*

*Note: Green highlighted values indicate significant decreasing trend, Pink highlighted values indicate significant increasing trend and bold values are Modified Mann Kendell test values.*

(-1.1mm/year), -3.28 (-0.8mm/year), -2.77 (-1.1mm/year) and -2.51 (-1.2mm/year) respectively in Winter season. Pemagatshel station located at the altitude of 1648 meter shows a significant decreasing trend -2.09(-8.9mm/year) magnitude in annual. Damphu Table 2 Sens slope test station under Tsirang district located at an altitude of 1520m shows a significant decreasing trend -2.84 (-10.1mm/year), -2.03(-1.0mm/year) and -2.66(-4.1mm/year) in annual, winter and pre monsoon season respectively. Kanglung station also shows a significant decreasing trend -1.99(-4.5mm/year) and -2.12(-4.1mm/year) in annual and monsoon season respectively.

In the lower zone, Deothang station under Samdrup Jongkhar district located at the altitude of 800 meter, Phuntsholing station under Chhukha district located at the altitude of 220 meter and Sibsoo station under Samtse district located at the altitude of 550 meter shows decreasing trend -2.51 (-2.8mm/year), -2.34 (-4.8mm/year) and -2.81(-2.0mm/year) magnitude respectively in winter season. Sibsoo station located at the altitude of 550 meter shows a significant increasing trend +2.19(23.0mm/year) magnitude in monsoon season. Bhur station under Sarpang district located at the altitude of 375 m shows significant decreasing trend -2.97(-8.3mm/year) and -2.64(-5.7mm/year) in pre monsoon and post monsoon season respectively. Phuntsholing station also shows

| Station | Annual | | Winter | | Pre-Monsoon | | Monsoon | | Post-Monsoon | |
|---|---|---|---|---|---|---|---|---|---|---|
| Class A | Sen's Slope | Mean | Sen's Slope | Mean | Sen's Slope | Mean | Sen's Slope | Mean | Sen's Slope | Mean |
| Chamkhar | 0.0 | 488.4 | -0.1 | 21.8 | 2.4 | 173.6 | -2.2 | 488.4 | 0.0 | 59.0 |
| Gasa | -10.2 | 1304.1 | -0.9 | 74.4 | -0.9 | 801.5 | -3.9 | 1304.1 | -1.3 | 182.4 |
| Haa | -0.2 | 625.7 | -0.1 | 30.5 | 0.4 | 164.6 | -1.5 | 625.7 | 0.0 | 60.2 |
| Paro | -2.1 | 458.5 | 0.0 | 26.8 | 0.2 | 114.1 | -3.2 | 458.5 | 0.0 | 46.8 |
| Simtokha | -1.9 | 473.0 | -0.2 | 23.4 | 0.0 | 103.7 | -3.7 | 473.0 | 0.0 | 40.8 |
| Trongsa | 3.0 | 839.2 | -0.6 | 40.7 | 1.2 | 287.8 | 0.0 | 839.2 | 0.5 | 80.1 |
| Dagana | -4.9 | 1217.6 | -1.2 | 55.9 | -3.1 | 314.6 | -1.7 | 1217.6 | 0.0 | 115.2 |
| Damphu | -10.1 | 1346.8 | -1.0 | 37.4 | -4.1 | 260.5 | -3.0 | 1346.8 | -1.8 | 110.8 |
| Kanglung | -4.5 | 791.4 | -1.1 | 46.6 | 0.0 | 270.7 | -4.1 | 791.4 | 0.0 | 77.2 |
| Mongar | -0.5 | 649.9 | -0.8 | 29.5 | 0.0 | 219.1 | -0.7 | 649.9 | 0.0 | 72.7 |
| Pemagatshel | -8.9 | 1273.8 | -1.1 | 54.8 | -2.4 | 389.8 | -5.0 | 1273.8 | -2.5 | 131.5 |
| Punakha | -2.4 | 564.0 | -0.8 | 38.0 | 0.0 | 137.9 | -2.8 | 564.0 | 0.0 | 50.9 |
| Tamangchu | -1.2 | 569.7 | 0.0 | 28.7 | 2.9 | 215.1 | -5.5 | 569.7 | 0.0 | 67.0 |
| Trashiyangtse | -0.6 | 774.1 | -0.3 | 35.1 | 1.9 | 281.7 | -2.4 | 774.1 | 0.0 | 83.0 |
| Wangdi | 0.0 | 482.0 | -0.3 | 19.1 | 0.3 | 117.7 | -0.1 | 482.0 | 0.0 | 44.7 |
| Zhemgang | -1.2 | 1026.2 | -1.1 | 46.9 | 0.1 | 248.4 | -1.8 | 1026.2 | 0.0 | 81.7 |
| Bhur | 0.0 | 4019.9 | -2.3 | 85.2 | -8.3 | 800.1 | 7.4 | 4019.9 | -5.7 | 249.7 |
| Deothang | 0.0 | 2590.8 | -2.8 | 80.5 | -1.5 | 801.5 | 0.0 | 2590.8 | -1.4 | 192.6 |
| Phuntsholing | -24.4 | 2965.9 | -4.8 | 102.1 | -12.8 | 742.4 | -1.1 | 2965.9 | -2.5 | 191.2 |
| Sibsoo | 23.7 | 3792.1 | -2.0 | 80.9 | 3.5 | 1001.2 | 23.0 | 3792.1 | -1.4 | 250.3 |

*Note: Orange highlighted values indicate magnitude of decreasing trend, Pink highlighted values indicate magnitude of increasing trend.*

significant decreasing trend -2.66(-2.5mm/year) in pre monsoon season. It is evident from the analysis that there is no significant increasing or decreasing annual trend of rainfall in both lower and upper altitude zone where as in the middle altitude zone Damphu, Kanglung and Pemagatshel districts shows a significant annual decreasing trend of rainfall over the study period. All the four districts Bhur, Deothang, Phuntsholing and Sibsoo in the lower altitude zone shows a significant decreasing trend of rainfall in winter season over the study period.

In the higher altitude zone, no significant annual as well as seasonal trend of rainfall is observed in Haa, Trongsa and Simtokha districts. In the similar manner no significant annual and seasonal trend is observed in Trashiyangtse and Wangdi district in the middle altitude zone over the study period.

REFERENCES

[1] Aggarwal, R. K., Mahajan, P. K., Negi, Y. S., & Bhardwaj, S. K. (2015). Trend Analysis of Weather Parameters and People Perception in Kullu District of Western Himalayan Region. 3(1), 24–33. https://doi.org/10.13189/eer.2015.030104

[2] Basistha, A., Arya, D. S., & Goel, N. K. (2009). Analysis of historical changes in rainfall in the Indian Himalayas. 572(June 2008), 555–572. https://doi.org/10.1002/joc

[3] Carlo, M. (2013). Exploring the ability of the Pettitt method for detecting change point by Exploring the ability of the Pettitt method for detecting change point by Monte Carlo simulation. (February 2015). https://doi.org/10.1007/s00477-013-0814-y

[4] Dorji, A. U., Olesen, J. E., Bøcher, P. K., Seidenkrantz, M. S., Dorji, U., Olesen, J. E., … Seidenkrantz, M. S. (2019). Spatial Variation of Temperature and Precipitation in Bhutan and Links to Vegetation and Land Cover Spatial Variation of Temperature and Precipitation in Bhutan and Links to Vegetation and Land Cover. 36(May), 66–79.

[5] Hamed, K. H., & Rao, A. R. (1998). A modified Mann-Kendall trend test for autocorrelated data. 204, 182–196.

[6] Jaswal, A. K., Bhan, S. C., Karandikar, A. S., & Gujar, M. K. (2015). Seasonal and annual rainfall trends in

Himachal Pradesh during 1951-2005 Study area which lies in the Western Himalayas , bounded by Jammu. 2(April), 247–264.

[7] Kang, H. (2013). The prevention and handling of the missing data. 64(5), 402–406.

[8] Kripalani, R. H., Kulkarni, A., & Sabade, S. S. (2003). Indian Monsoon Variability in a Global Warming Scenario. 189–206.

[8] Marques, R., Santos, C. A. G., Moreira, M., Valeriano, C., & Isabella, C. L. S. (2015). Rainfall and river flow trends using Mann – Kendall and Sen ' s slope estimator statistical tests in the Cobres River basin. 1205–1221. https://doi.org/10.1007/s11069-015-1644-7

[9] Pandit, D. V. (2016). Seasonal Rainfall Trend Analysis. 6(7), 69–73.

[10] Sattari, M., Rezazadeh-joudi, A., & Kusiak, A. (2016). Uncorrected Proof missing data in precipitation studies Uncorrected Proof. 1–13. https://doi.org/10.2166/nh.2016.364

[11] Shahnawaz, S. (2016). A Zonal Analysis of the Climatic Conditions in Bhutan A Zonal Analysis of the Climatic Conditions in Bhutan Shahnawaz and Josef Strobl. (April 2015).

[12] Shahnawaz, & Strobl, J. (2015). A Zonal Analysis of the Climatic Conditions in Bhutan. Climate Change, Environment and Development in Bhutan, (1), 1–22. Retrieved from http://www.cnr.edu.bt/CCED/01_Shahnawaz-Strobl_ClimaticConditionsInBhutan_P_01-22.pdf

[13] Shrestha, A. B., Wake, C. P., Dibb, J. E., & Mayewski, P. A. (2000). Precipitation fluctuation in the Nepal Himalaya and its vicinity and relationship with some large scale. 327, 317–327.

[14] Taxak, A. K., Murumkar, A. R., & Arya,

D. S. (2014). Long term spatial and temporal rainfall trends and homogeneity analysis in Wainganga basin , Central India. Weather and Climate Extremes, 4, 50–61. https://doi.org/10.1016/j.wace.2014.04.005

[15] Toreti, A., Kuglitsch, F. G., Xoplaki, E., & Della-marta, P. M. (2011). A note on the use of the standard normal homogeneity test to detect inhomogeneities in climatic time series. (March). https://doi.org/10.1002/joc.20

# Design and Analysis of Seismic Isolation Device

Karma Dorji[1], Karma Dema, Karma Singye, Karma Wangda, Karma wangyel, Yenten Tshering, Tandin Wangdi[2]
Department of Mechanical Engineering,
Jigme Namgyel Engineering College, Royal University of Bhutan, Dewathang, Bhutan

*Email: karmat.dorji.90@gmail.com[1] , tandinwangdi@jnec.edu.bt[2]*

***Abstract - This project is on the design of seismic isolation device to absorb the shock in the structure during earthquake vibration. The motion developed by earth vibration damages most of the structure and valuable cultural assets. Therefore, to protect the valuable structures, a design of seismic isolation device is developed which can favor a high level of building performance under lateral load, providing protection to structural and non-structural elements. The operating mechanism of the device is based on the pendulum type of seismic isolation device. The developed design will absorb the shock and reduce the stiffness in the structure. It comprises of the main body to hold the entire components. When the irregular vibration of motion arises, it will neutralize the horizontal motion on the structural plate.***

***Key words: Seismic Isolation Device, Principle of Pendulum***

## 1. INTRODUCTION

The designed seismic isolation device functions to prevent unexpected damages to structure caused during earthquake. It has the capacity to resist the earthquake vibration on load where it can increase the frequency and reduce the force applied on the structure. In addition, seismic isolation device reduces response of the superstructure by decoupling the building from the ground, decreasing the base shear and interstate drift in the superstructure. The reduction of an acceleration in the structure depends on the force deflection characteristics of the isolators and may not be as significant as the reduction of drift. This falling of drift in the superstructure secures the structural components as well as non-structural components. The acceleration reduction of drift protects non-structural components through sensitive to acceleration induced damage. Therefore, the base isolation can be protected effectively from seismic response of different structural systems by reducing the expected damage.

## 2. LITERATURE REVIEW

'Designed of seismic isolation device' he firstly implements idea on base isolation device [1]. He applied the concept of base isolation in foundation design for the Imperial Hotel in Tokyo, under the site was an eight feet layer of good soil and below that a layer of soft mud. From this idea of floating structure came into picture for the resistance of earthquake shock.

'Earthquake resistant design of structures using the variable frequency pendulum isolator'[2], he compared between LRB and FPB for a five storey RC framed structure. Base isolators improved the performance of structure during earthquake. Isolators reduced the roof level acceleration, shear, and inter- storey drift. He stated that the base isolator has become an accepted design alternative for earthquake hazard migration for various structure. The most common feature of such system are a shift in a natural frequency of the structure to a lower value, and an increase in structural damping by hysteretic dissipation.

'Experimental and analytical study of the bi-directional behaviour of the triple Friction Pendulum isolator [3]', the author did a comparison between the RC building with fixed and isolated base with rubber bearings and Friction isolators using response spectrum method and finite element method. In case of friction type isolator base shear and relative drift decreases. The value of relative drift is inversely properly to the number of stories. Is code giving the maximum displacement value where Euro code give the minimum displacement value for the building with fixed base.

'Estimating floor spectra in multiple degree of freedom systems [4]', they did comparison between the effects of high-density rubber bearing and friction pendulum system on a hospital building.

He concluded that the base shear reduced in case of isolated structure. The storey displacement has very little variation. Value of storey drift, acceleration, displacement shows very little variation when storey height changes in case of high damping rubber bearings.

'Modelling curved surface sliding bearings with bilinear constitutive law: effects on the response of seismically isolated buildings [5]' It emphasized the effect of hybrid isolation technique on the response of a multi storey building under seismic loads. He used Base isolation and seismic dampers to minimize inter-story drifts and floor acceleration. He concluded that displacement and base shear is inversely proportional to storey height when combined isolation was used.

'Numerical Modelling of Variable Friction Base Isolators, the position of Friction dampers and Base isolator [6]', in this authors have surveyed the principles, benefits, and the feasibility of seismic isolation device. He stated that base isolators are effective tools to favor a high level of building performance under lateral load, providing protection to both structural and non-structural elements. The structure with triple pendulum base isolator has very less drift. Floor displacement is highest in case of base isolated type frame. The frame which has base isolator reduced bending moment of the frame significantly.

## 3. METHODOLOGY

### *Drawing*

The designing of seismic isolation devices involves many activities in different sections of works including the selection of appropriate devices, multi-task process, consideration aspects, etc. In this, it comprises of following a designed process.

### *3-D Design drawing*

The following figure 1 shows an overall three-dimensional (3-D) design drawing to reveal the exact product, clear information on the designs for easy fabrication work.

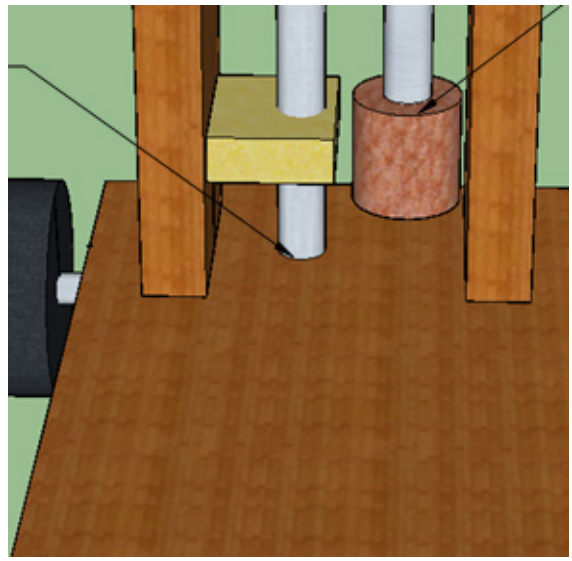


*Figure 1: 3D drawing of seismic isolation device*

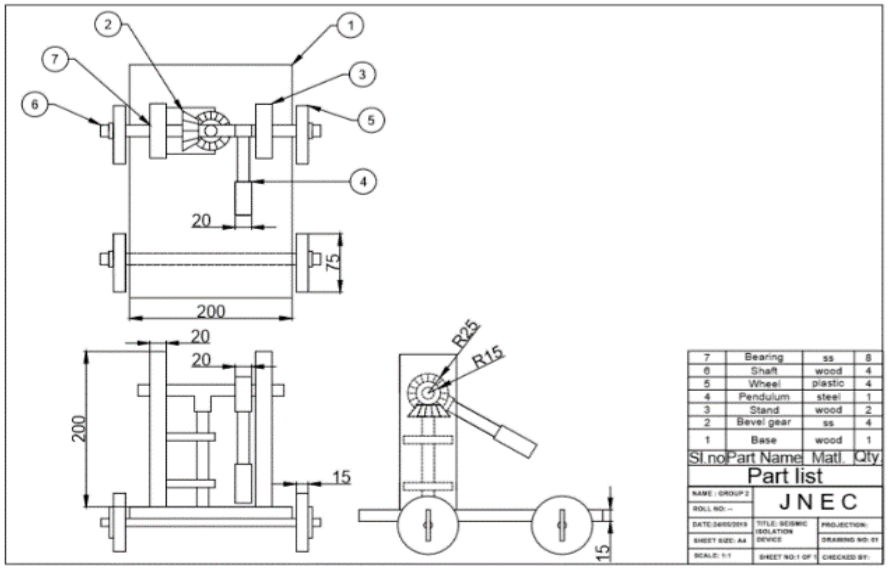



*Figure 2: Detail drawing of seismic isolation device*

### *2D Drawing*

Figure 2 illustrates the orthographic views of designed project on seismic isolation device to define the true size and features. The 3-D drawing will simply depict how the product looks and will not suffix in the developing process of the project.

## 4. OVERVIEW OF THE SYSTEM

### *Working Principle*

As

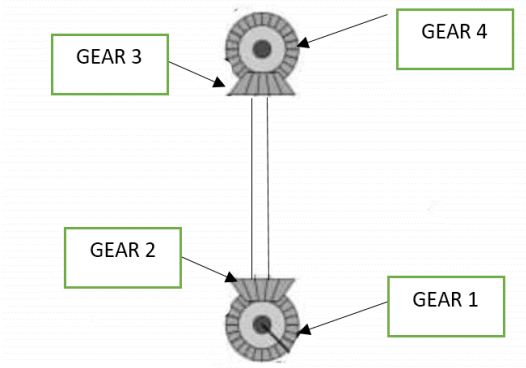



*Figure 3: Gear connection of the device*

shown in Figure 1, there is available a horizontal seismic isolation device which has a horizontal Support mechanism comprising a wheels, gears, shaft, bearings and base.

Gear 1 is assembled with shaft of back wheel and the wheel is connected to the shaft 1 by the two bevel gears (gear 1 and 2) and the shaft is again connected by the shaft 2 by the two bevel gears (gear 3 and 4). The pendulum is also connected to the shaft 2

### *Forward movement*

In the forward movement, the gear 1 will rotate in a clockwise direction to transmit the rotary motion to the gear 2 through its attached shaft at the end, making the gear 2 to rotate in an anticlockwise direction. The same rotary motion from gear 2 is further transmitted to the gear 3, to obtain clockwise rotation. The final gear 4 will rotate in the anticlockwise direction for a certain angle as it is connected to pendulum shaft.

### *Backward movement*

During the backward movement of the device, gear 1 will rotate anticlockwise to transmit the rotary motion to the gear 2 through its attached shaft at the end, making the gear 2 to rotate in clockwise direction. The same rotary motion from gear2 is further transmitted to the gear 3, to obtain anti-clockwise rotation. The final gear 4 will rotate in clockwise direction for a certain angle as it is connected to pendulum shaft.

### *Analysis*

Figure 4 shows the analysis model of the ignition base and the transmission mechanism of the tire and Figure 4: analytical model of SID

the pendulum of the truck. The shaft of the tire and the pendulum is connected via a propeller shaft of a gear, and the pendulum rotates in proportional to the horizontal displacement of the truck. Furthermore, the speed reduction ratio is to change the gear ratio of two or more gears.

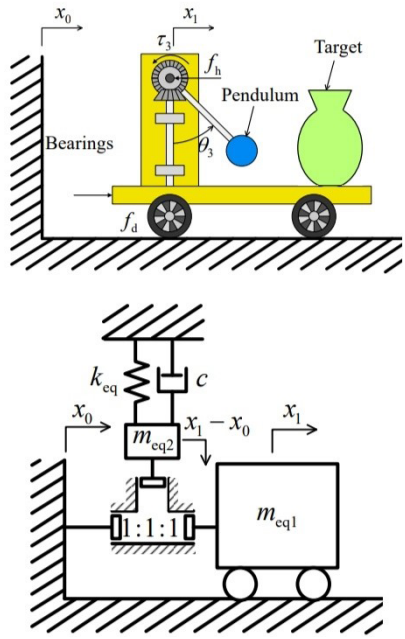



*Figure 4: analytical model of SID*

Considering;

X0= amplitude of ground displacement

X1= amplitude of tires to the ground

fd= forces of tires to the ground

fh= forces of the pendulum

$\theta_3$ = angular displacement made by the pendulum

The relationship between the displacement and the rotation angle of the tires is

$X_1 - X_0 = R_1 \theta_1$

The relationship of rotation angle of each shaft

$$\theta_1 = {}^{1}/_{gr1}\ \theta_2$$

$$\theta_2 = {}^{1}/_{gr2}\ \theta_3$$

This is as follow

$$\theta_3 = \alpha\ (x_1 - x_0)$$

$$\alpha = {}^{1}/_{r_1 g_{r1}}$$

By using the law of second order system

$$x_1 - x_0 = {}^{\emptyset_{3lim}}/_{\alpha}$$

## 5. CONCLUSION AND FUTURE SCOPE

In this study, we proposed a seismic isolation unit and a dynamic absorber using the restoring force of the pendulum. In the rotational direction of the same direction type, reverse type, perpendicular type three-way, seismic isolation method, vibration damping method. The equations of motion were derived and the equivalent machine model was shown in the

seismic isolation units, because the pendulum moves in proportion to the relative acceleration, the inertial force proportional to the relative acceleration and the presence of an anti-resonance point was confirmed. In the same direction type, the frequency of natural frequencies can be adjusted, and the seismic isolation performance is higher near the anti-resonance point, but was confirmed to be a bunch.

On the other hand, compared to the same directional type, the number of motions is high, but the convergence value can be zero by adjusting the specifications. If the amplitude is not able to be greatly linearized, the numerical analysis in the case of seismic isolation table is being confirmed that nonlinear term works in the direction to reduce vibration.

Moreover, in the case of dynamic absorber, the optimum adjustment type obtained in linear system under the effect of nonlinear term is confirmed that the vibration could not be reduced. Both the seismic isolation table and the dynamic vibration absorber is validity of the theoretical analysis was confirmed, and the proposed method was effective.

Future scope

Seismic isolation device a balancing type device which can play vital role in protecting the ornament from breaking. Our project mainly focuses on the designing and analyzing of seismic isolation device. By the elapsing of time, ornaments of olden days are becoming an important things to be protected. Therefore, to overcome this problem the application of seismic isolation device come to picture. Here in our project we have just designed and done few analysis of the SI device and we have proved that this device can be used by building up the prototype. In future, this device can be manufactured and use in the places like museum and household for protecting ornament. And also can be used in multidirectional direction of seismic caused by the earthquake.VI.

## 6. ACKNOWLEDGEMENT

The team would like to thank the management of Jigme Namgyel Engineering College for the opportunity to work on the final year project.

We would like thank Mr. Tandin Wangdi, Department of Mechanical Engineering (DME) for guidance during the project

We would like to express our gratitude to Professor Junichi Kurata, Department of Mechanical Engineering, Kansai University, Suita for providing information and advices.

Finally, we would like to acknowledge the support received from the Department of Mechanical Engineering, JNEC.

REFERENCES

[1] Frank, N.B., (1921), 'Designed of seismic isolation device, Earthquake and Structures 51(2)

[2] Murnal P., Sinha R., (2002). Earthquake resistant design of structures using the variable frequency pendulum isolator. Journal of Structural Engineering, 128(7), 870–880.

[3]Becker T.C., Mahin, S.A., (2012). Experimental and analytical study of the bi-directional behaviour of the triple Friction Pendulum isolator, Earthq Eng Struct Dyn, 41(3):355–373.

[4] Calvi P.M., Sullivan T, (2014). Estimating floor spectra in multiple degree of freedom systems, Earthquake and Structures, 7 (1), 17-38.

[5] Faga E., Ceresa P., Nascimbene R., Moratti M., Pavese A., (2015). Modelling curved surface sliding bearings with bilinear constitutive law: effects on the response of seismically isolated buildings, Materials and Structures.

[6] Calvi P.M., Ruggiero D., (2016). Numerical Modelling of Variable Friction Base Isolators, Bulletin of Earthquake Engineering, 14(2), 549-568.

# Optimum Allocation of SVC in National Grid of Bhutan using Load Flow Analysis

Deepak Bhattarai, Aita Bdr. Subba, Sonam Gyeltshen, Damber Singh Ghishing, Shah Bir Rai[1]
Department of Electrical Engineering,
Jigme Namgyel Engineering College, Royal University of Bhutan, Dewathang, Bhutan

*Email: shahbirrai@jnec.edu.bt[1]*

***Abstract— This paper discusses optimal allocation of Static Var Compensator (SVC) in national grid of Bhutan based on sensitivity analysis using Voltage Profile Index (VPI). The variable shunt susceptance model of SVC was considered and Matlab program was used to incorporate this model in Newton Raphson load flow study. Further, same Matlab program was used to compute VPI, lines losses and reactive power absorbed or injected by SVC which forms the basis for optimal placement of SVC. In order to carry out comparative study, load flow for base case without SVC and in second case, with SVC integrated in network was performed using PSS/E. The main objective of incorporating SVC is to determine the percentage improvement of voltage of the weakest bus as well as overall voltage profile and also to realize line losses reduction in the network. The study has found out the superiority of operation of SVC and its impact in the whole network when placed at proposed bus.***

***Keywords—Load flow analysis, Newton Raphson, Power loss, Susceptance, Voltage profile index, Weakest bus.***

## 1. INTRODUCTION

In modern Bhutan, electricity demand has been growing exponentially due to development of various industrial sectors, expansion of towns and cities which simultaneously leads to extension of complex transmission line and inter-connection of multi-generator to the national grid. Therefore, power system stability, power losses and monitoring the health of system network are significant issues which need to be address and analyze carefully in order to ensure reliable and secure energy supply. The total energy demand of Bhutan is expected to be 6,404.46 MU with a peak demand of 1,150 MW by 2040. As per the demand forecast, the average annual load growth was found out to be 4.4% [1]. For the last few decades, power grid across the globe has been emerging as one of most complex and advance network systems with implementation of sophisticated modern technology. Similarly, one of fast-growing technology in power system engineering is concepts of FACTS device which is a power electronic based system and other static equipment that provide control over one or more AC transmission system parameters to enhance controllability and increase power transfer capability [2].

FACTS controller can be either series connected or shunt connected or combination of both types. These devices are placed at various location in the electrical power system network depending on requirement and their purpose. Static Var Compensator (SVC) is shunt connected FACTS controller which is a variable impedance device that controls the current flowing through a reactor using back to back connected thyristor valves. With suitable control, it allows appropriate voltage regulation by injecting reactive power into the system, so that the voltage magnitude of the bus connected to SVC can be maintained constant [3]. There are different types of SVC available such as Thyristor Controlled Reactor (TCR), Thyristor Switched Capacitor (TSC), Fixed Capacitor plus Thyristor Controlled Reactor (FC-TCR) and Thyristor Controlled Reactor plus Thyristor Switched Capacitor (TCR–TSC). The use of TCR plus TSC, SVC continuously monitors reactive power, both the inductive and the capacitive in the entire control range. The characteristics of Thyristor Controlled Reactor plus Thyristor Switched Capacitor are: It has a continuous control and eliminates the harmonics through TSC control. The losses are less and more flexible. Therefore, this

Appropriate allocation of SVC plays a vital roles in maintaining the voltage within the desired limit. SVC application in power system enhance voltage stability, minimizes line losses and improves voltage

regulation [4]. It requires optimization to locate the optimal SVC location and capacity. Optimal means that the SVC can reduce power losses and voltage deviation [5]. Some of the common optimization technique used for the optimal placement of SVC in the networks are Genetic algorithm (GA), Particle swarm optimization (PSO), Bees algorithm, Voltage collapse proximity indicator (VCPI) and Sensitivity analysis. In general the best location is at a point where voltage swings are greatest [6]. In this research, sensitivity analysis using Voltage Profile Index (VPI) is adopted for finding optimum allocation of SVC in the mesh network.

The paper is organized as follows: Section II gives a brief description of single line diagram network of Bhutan. Section III describes the modelling of SVC. Section IV presents on the technique to find the optimum location of SVC. Finally, Section V describes the observation and results.

## 2. SINGLE LINE DIAGRAM OF NATIONAL GRID OF BHUTAN

The voltage level used for transmission of electricity in Bhutan are 66 kV, 132 kV, 220 kV and 400 kV and it is connected to Indian grid which includes 132 kV through Rangia and Salakati, 220 kV double circuit through Birpara and 400 kV three lines through Siliguri. The transmission network in Bhutan is divided into two regional grid namely Eastern and

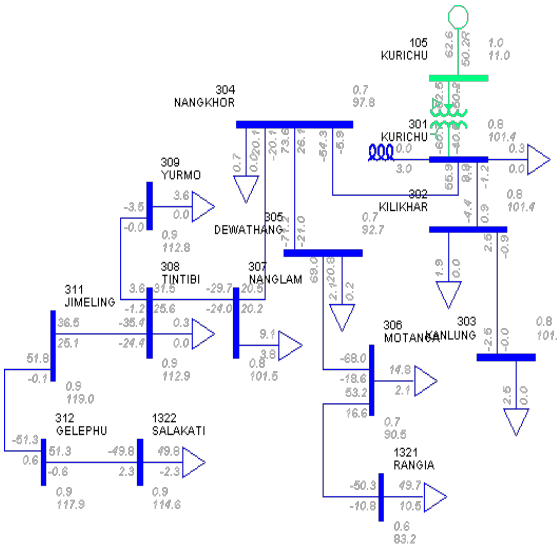



*Fig. 1: Eastern grid of Bhutan*

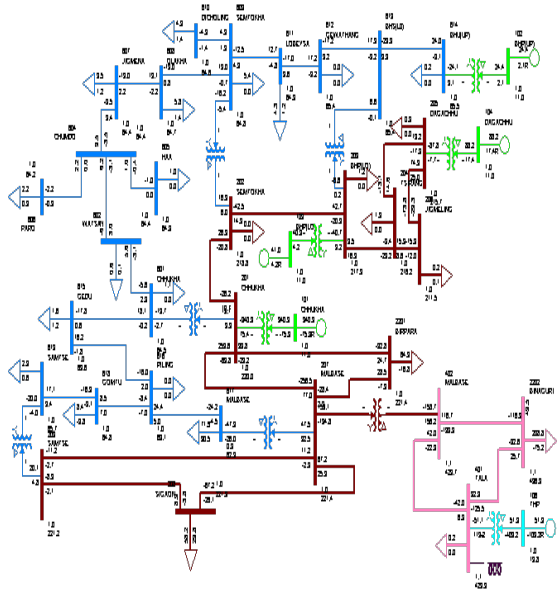


*Fig. 2: Western grid of Bhutan.*

Western grids. The two grids are being interconnected at Jigmeling (pooling station). Eastern grids have a transmission voltage level of 132 kV and Western grid have a transmission voltage level ranging from 66 kV to 400 kV.

## 3. MODELING OF STATIC VAR COMPENSATOR

The modelling of SVC can be done in two methods [7], the variable shunt susceptances model and firing angle model. In variable shunt susceptances model, the susceptance is automatically regulated to obtain a desired voltage within the limit. The equivalent circuit of variable shunt susceptance model of SVC is shown in Fig.3. In load flow analysis, Jacobian

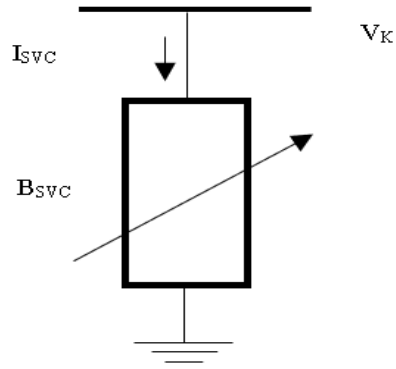



*Fig. 3: Variable Shunt Susceptance model*

matrix in conventional Newton Raphson technique must be reordered and re-dimension during iterative solution for implementing this model. In variable

$$Q_{SVC} = Q_k = -v_k^2 B_{SVC} \quad (2)$$

shunt susceptances model of SVC its reactance is adjusted automatically such that the specified voltage magnitude is obtained by satisfying the various system constraints [8].

$$\begin{bmatrix} \Delta P_k \\ \Delta Q_k \end{bmatrix}^i = \begin{bmatrix} 0 & 0 \\ 0 & Q_k \end{bmatrix}^i \quad \begin{bmatrix} \Delta\theta_k \\ \Delta B_{SVC}/B_{SVC} \end{bmatrix}^i \quad (3)$$

$$B_{SVC}^{(i)} = B_{SVC}^{(i-1)} + \left(\frac{\Delta B_{SVC}}{B_{SVC}}\right)^{(i)} B_{SVC}^{(i-1)} \quad (4)$$

From above figure, the current drawn by the SVC is

$I_{SVC} = jB_{SVC} V_k$ (1)

The reactive power equation is given by:

The total susceptance $B_{SVC}$ is considered as state variables and the linearized equation of SVC is given as:

At last iteration, the variable shunt susceptance $B_{SVC}$ was calculated by given formula

This model is an improved version of SVC models

| *Parameters* | *Per Unit* |
|---|---|
| *Initial Susceptance Value* | *0.02* |
| *Lower limit Susceptance Value* | *-0.25* |
| *Higher limit Susceptance Value* | *0.25* |
| *Targeted Voltage Value* | *1* |

[9]. This value of susceptance is the total SVC susceptance required to improve voltage profile of system.

Matlab program was used to incorporate Static Var Compensator (SVC) variable shunt susceptance model within the Newton–Raphson power flow algorithm. The SVC data used for modelling is tabulated in Table I.

TABLE I. SVC DATA

3.OPTIMAL PLACEMENT OF STATIC VAR COMPENSATOR

Usually placing adequate shunt FACTS devices at the weakest bus enhances static voltage stability margins. The weakest bus is defined as the bus, which is nearest to experiencing a voltage collapse.

$$VPI_k = \sum_{k=1}^{n} (V_k - 1)^2 \quad (5)$$

In this paper, Matlab program was used to find VPI and total losses and these two parameters are main criteria for optimal placement of SVC.

The problem has been formulated as a dual objective function: (i) minimize losses (ii) minimum voltage

$$P_{loss} = P_{loss} = \sum_{i=1}^{ntl} P_{loss}^i \quad (6)$$

profile index (VPI).

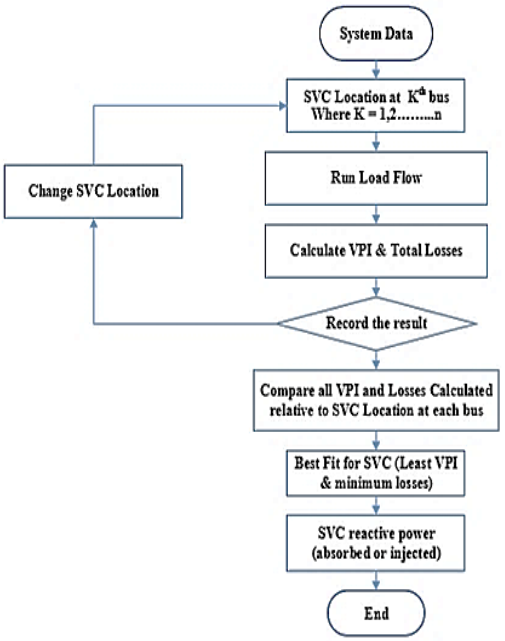



*Fig. 4: Proposed algorithm to identify the weakest bus*

1. Voltage Profile Index(VPI)

When SVC is placed at bus K, VPI for bus K is defined as:

Where, 'Vk'is voltage at Kth bus and 'n' is number of buses. The bus with least VPI will be picked as the best location for the SVC placement Fig. 4: Proposed algorithm to identify the weakest bus

2. Losses minimize

Where ntl is number of transmission lines and is loss at transmission line.

Fig. 4 shows the proposed Matlab based algorithm used for optimal allocation of SVC using sentivitity analysis.

## 4. RESULT AND DISCUSSION

In this research, to identify the weakest bus for the optimum allocation of SVC in power system network of Bhutan, sensitivity analysis technique based on voltage profile index was implemented. The Matlab program was written to compute VPI and analyze power losses. To obtain better result and analysis, most sensitive buses as shown in table below are selected to find best possible location for SVC. Usually, the bus with a minimum voltage profile index is considered as the weakest bus in the network. If SVC is integrated at bus with least VPI, it is found that overall voltage profile is enhanced as well as line losses is significantly reduced. To maintain desire voltage at the weakest bus (SVC Location), the value of reactive power that needs to be injected to the system or absorbed from the system was also determined based on computation of variable susceptance. The voltage profile index of selected bus is tabulated in table II.

| Bus Name | Bus No | Bus Type | VPI | Losses | Susceptance | SVC Reactive Power |
|---|---|---|---|---|---|---|
| Malbase, 400 kV | 402 | 3 | 0.1411 | 0.134 | -0.25 | 0.525 |
| Binaguri, 400 kV | 2202 | 3 | 0.3094 | 0.1366 | -0.25 | 0.25 |
| Chhukha, 66 kV | 601 | 3 | 0.0373 | 0.1305 | -0.0329 | 0.0329 |
| Gedu, 66 kV | 615 | 3 | 0.0346 | 0.1366 | 0.1744 | -0.1744 |
| P/ling, 66 kV | 616 | 3 | 0.0231 | 0.1276 | 0.1875 | -0.1875 |
| Malbase, 66 kV | 617 | 3 | 0.0191 | 0.1225 | 0.1897 | -0.1897 |
| Gomtu, 66 kV | 618 | 3 | 0.0194 | 0.1218 | 0.1549 | -0.1549 |
| Samtse, 66 kV | 619 | 3 | 0.0262 | 0.1325 | 0.1459 | -0.1459 |
| Tala, 400 kV | 401 | 3 | 0.3094 | 0.1324 | -0.25 | 0.25 |

TABLE II. VOLTAGE PROFILE INDEX OF SELECTED BUS

From the table II, it is clear that when SVC is placed at load bus number 617, Malbase 66 kV, the voltage profile index (VPI) is least, however real power losses relative to bus number 618 is not minimum. Although, integrating SVC at bus number 618 is better option based on global active power losses,

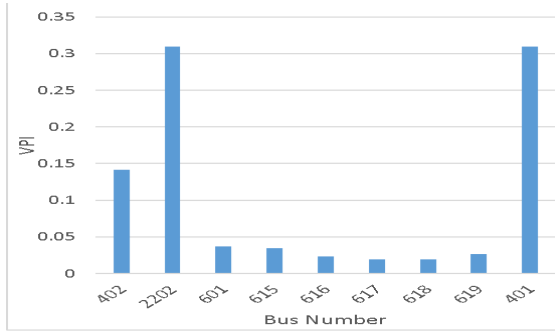



*Fig. 5: VPI variation for selected bus*

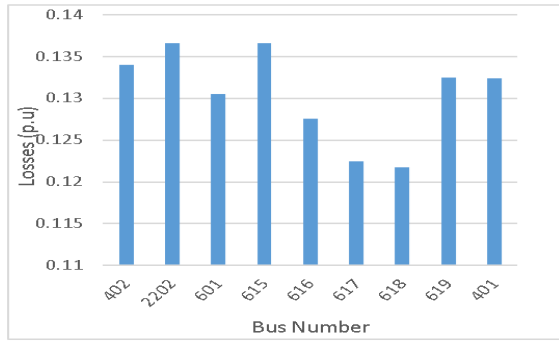



*Fig. 6: Power losses variation when SVC is placed at selected*

but difference in losses is very small (i.e. 0.7 kW). Moreover, VPI is comparatively dominant at bus number 617 and therefore, bus number 617 will be most appropriate and optimal location for SVC installation. To adjust 1 p.u. voltage at Malbase 66 kV, the SVC has to inject 0.1897 p.u. of reactive power that is 18.97 MVAr.

The figures below present graphical representation of voltage profile index (VPI) and corresponding real power losses when SVC is placed at each selected bus. The VPI is maximum when SVC is placed at bus number 2202, Binaguri, indicating large voltage deviation from reference voltage and least VPI at bus

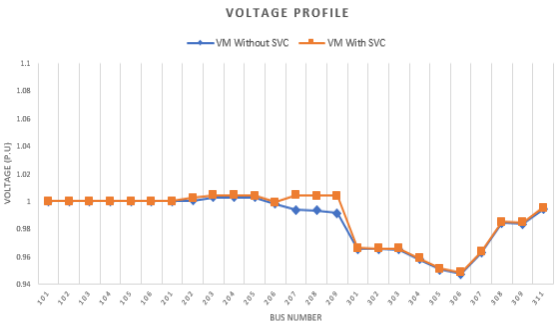



*Fig. 7: Voltage profile for first 25 bus with and without SVC*

number 617 i.e. 0.0191 signifies suitable location of SVC with minimum voltage deviation.

### *A. Voltage profile with and without SVC*

The Fig.7 depicts voltage profile for first 25 buses with and without SVC installation. Initially voltage profile in each case remain steady that is 1 p.u. but with the installation of SVC, voltage profile is significantly improved between bus number 206 to 301 and further a little improvement is seen with SVC. Since reactive power is closely related to voltage, a small change in reactive power will

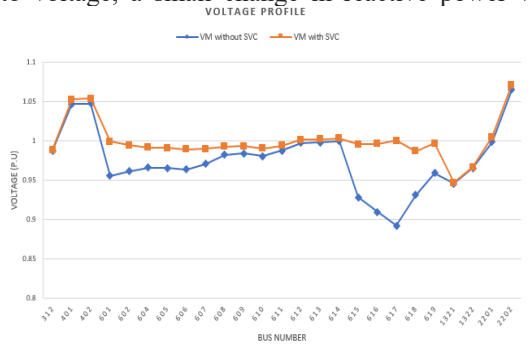



*Fig. 8: Voltage profile of remaining 25 bus with and without SVC*

have great impact on voltage profile. Here, SVC injects external reactive power into system which automatically boost low voltage level to desire limit.

For remaining 25 buses, graphical representation of voltage magnitude for two cases with and without SVC is illustrated in Fig. 8. At two 400 kV bus namely bus number 401 and 402, incorporating SVC results in increased in voltage level, however voltage profile in rest of the buses is significantly improved. Since voltage profile at most of buses is below 1 p.u. which indicates that SVC need to injects reactive power into the grid to boost overall voltage closer to unity and therefore, reactive power injected by SVC seems to be more dominant than drawn by it. Hence, voltage at bus number 401 and 402 is slightly deviated from expected result.

### *B. Power losses with and without incorporating SVC*

As per this research, active power loss has been

TABLE III. POWER LOSSES WITH AND WITH-OUT INCORPORATING SVC

| Generation | | Load | | Losses | |
|---|---|---|---|---|---|
| MW | MVAr | MW | MVAr | MW | MVAr |
| 601.25 | 149.1 | 583.78 | 12.2 | 17.47 | 145.88 |
| 601.25 | 72 | 583.78 | 12.2 | 17.97 | 152.14 |

reduced by 0.5 MW which is 2.78% and reactive power by 6.26 MVAr which is 4.11% after incorporating of SVC compensator in its optimum

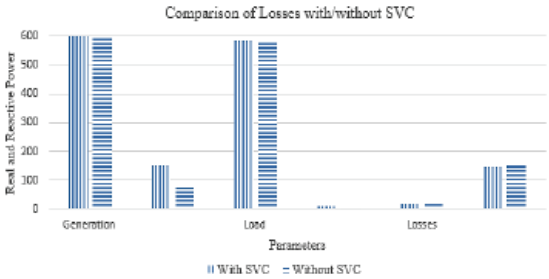



*Fig. 9: Comparison of loss with and without SVC*

location that is Malbase 66 kV bus. From this result, it is interesting to note that reactive power losses have been reduced by higher magnitude as compared to active power. Reason can be well understood if we consider power triangle, in which by compensation of reactive power, magnitude of active power remains same but power factor of the system is improved to

| Cases | Losses | |
|---|---|---|
| | MW | MVAr |
| Without SVC | 13.63 | 245 |
| With SVC | 12.46 | 203.43 |

better value.

It is quite clear that difference in line losses is apparent which means losses obtained in PSS/E is higher than that of Matlab, this is because in Matlab program the transformer and generation losses are ignored as data for these two machines are not taken into account. The value of active power, reactive power and losses is tabulated in Table III.

The comparison of values of power generation, load and losses in the power system network is shown in Fig. 9.

The results obtained from Matlab program is tabulated in Table IV.

TABLE IV. POWER LOSSES WITH AND WITHOUT INCORPORATING SVC BASED ON MATLAB PROGRAM

As swing bus generate or absorb active and reactive power in the system accordingly to maintain power balance. The swing bus contribution is flexible and usually hinged on power load demand and line losses. Tala was kept as the slack bus because it is the highest power generating plant in the country and while carrying out load flow analysis, there are lesser chances of exceeding the total installed capacity while generating or absorbing power. The swing bus result obtained was 44.7 MW and -68.4 MVAr.

## 5. CONCLUSION

In this research, optimum allocation and installation of variable shunt susceptance model Static Var Compensator (SVC) was carried out in national grid of Bhutan using sensitivity analysis. In order to show voltage control and line losses reduction capability of proposed SVC model, two power flow case studies were carried out for national grid. Firstly, voltage magnitude, voltage angle and power losses were found for base case without SVC. Further, sensitivity analysis using voltage profile index (VPI) was used to find optimal location of SVC and out of most sensitive selected buses, Malbase 66 kV bus with least VPI that is 0.0191 was preferred for SVC location. In second case, load flow study incorporating SVC was performed to compare result with base case load flow for further analysis.

From the research that has been carried out, it is possible to conclude that with SVC installed on the selected weakest bus, the overall voltage profile of the buses was regulated within desired limit. Moreover, real power loss was reduced by 0.5 MW that almost turn out to be 2.78% of the total losses and reactive power loss was minimized by 6.26 MVAr that is nearly 4.11% of the total losses in the system. Though the proposed approach has been instigated on national grid of Bhutan on research basis, but same can be implemented on practical power systems. Hence, the finding suggest that SVC is effective and promising FACTs device for controlling voltage profile and loss reduction in any power system network.

## 6. ACKNOWLEDGMENT

We are very grateful to our project guide Mr. Shah Bir Rai, Dean Student Affairs, for his continuous support and assistance in bringing up this project successfully. The group also would like to thank Mr. Cheten Tshering, the Manager of Bhutan

Power Cooperation Limited, Neylang substation, Dewathang, Samdrup Jongkhar, for his support related to software in the course of our project. Further, we would like extend our heartfelt gratitude to the Manager and his subordinate, Bhutan Power System Operator, Thimphu, for providing necessary data required for the project. Finally, we would like to acknowledge faculty and staff of Department of Electrical Engineering, JNEC for invaluable comments and suggestions.

REFERENCE

[1] National Transmission Grid Master Plan (NTGMP) of Bhutan-2018, Department of Hydropower & Power Systems, 2018.

[2] N. G. Hingorani and L. Gyugyl, Understanding FACTS, New York: A John Wiley & Sons, Inc, Publication, 2000.

[3] N. Palukuru, S. H. n. Dey and S. Paul, "Location of static var compensator in a multi-bus power system using unique network equivalent," Advances in Energy Research, vol. 3, pp. 235-249, 2015.

[4] R. Jena, S. Chirantan, S. C. Swain and P. C. Panda, "Load Flow Analysis and Optimal Allocation of SVC in nine bus Power system," IEEE International Conference on Technologies for Smart-City Energy Security and Power (ICSESP), 2018.

[5] H. . Y. Mulyadi, Y. Febriana and A. . G. Abdullah, "Optimization Placement of Static Var Compensator (Svc) on Electrical Transmission System 150 kV Based on Smart Computation," Materials Science and Engineering, 2018.

[6] H. Boudjella, F. Z. Gherbi and F. Lakdja, "Modelling and Simulation of Static VAr Compensator (SVC) in Power System Studies by MATLAB," ResearchGate, vol. 49, p. 450, 2008.

[7] C. R. F.-E. H. A.-P. a. C. A.-C. Enrique Acha, FACTS Modelling and Simulation in Power Networks, West Sussex: John Wiley and Sons Ltd, 2004.

[8] P. Jain and R. Dahiya , "Optimal placement of SVCs based on sensitivity analysis using VPI," in Conference on Electrical, Electronics and Computer Science, 2016.

[9] S. Udgir, S. Varshney and L. Srivastava , "Optimal Placement and Sizing of SVC for Voltage Security Enhancement," International Journal of Computer Applications, vol. 36, p. 6, 2011.

[10] F. Larki, H. M. Kelk, . M. Pishvaei, A. Johar and M. Joorabian , "Optimal Location of STATCOM and SVC Based on Contingency Voltage Stability by Using Continuation Power Flow:Case Studies of Khouzestan Power Networks in Iran," Second International Conference on Computer and Electrical Engineering, pp. 179-183, 209.

# Quiz Desktop Application

Kinley Dorji[1] , Tandin Dorji[2] ,Karma Tenzin[3], Younten Tshering[4], Sonam Wangmo[5],
Diploma in Computer System and Network
Department of Information Technology, Jigme Namgyel Engineering College
Royal University of Bhutan

*Email: kinleydorji166@gmail.com[1], tandindorji571@gmail.com[2], karmatenzinty@gmail.com[3], yountentshering@jnec.edu.bt[4], sonamwangmo@jnec.edu.bt[5]*

***Abstract - The main idea of this project is to develop a quiz application for the college that will be interactive and time saving while conducting quiz competition. Currently there is such application used by the college to conduct the quiz competition as a part of co-curricular activities. The quiz application is designed using different methods. The design will enable to conduct quiz at ease without having to take time, encounter unnecessary errors and minimize the use of other additional materials as well as assistance. To develop this project, modern waterfall model was used as methodology because such type of software development model is used when the project is small. It also reviews all the phases as to determine if the project is on the right path and whether to continue or discard the project. The quiz application has a platform where administrator can add and modify the questions, categorize the questions, and add or modify the participants accordingly. Update on the scores will alos be automatically taken care by the application system. It also provides additional features such as generating reports for the participants. This project was developed to facilitate the literary coordinator to conduct the quiz activities in the academic institution.***

## 1. INTRODUCTION

Quiz Desktop Application (QDA) which is named as Quiz-Master is an application that will be used while conducting the quizzes in the college. This project was developed to ensure that the quiz in the college would be conducted effectively considering the required resources such as manpower and the time constraints. Moreover, the system will take care the updates of the quiz questions and score report without error. The Quiz Desktop Application [QDA] process is fast, time saving and user friendly. The QDA was designed and developed to enhance the existing system of conducting quiz activities in the college as a part of co-curricular activities every semester. Current way demands more time, and requires additional resources. This system was developed to support the multiple participants taking the quiz at the same time.

## 2. RELATED WORK

The idea of using desktop application games is to engage students in the process of active learning which is not a new thing in the world [1]. Over the past several years, educators have been increasingly incorporating various games into their teaching curriculum to create an engaging learning environment for students. Although this can be very challenging and time consuming, but it would provide the learners with an interactive, collaborative and competitive environment that would motivate and encourage student participation in learning process.

Many games application was developed for the entertainment, creative and analytical thinking but at the same time, there were some other application designed to facilitate the learning. In “Game Plan. Technology and Learning”, nearly 70% of students learn through the visual presentation, active and interactive engagement [2]. Considering these, the QDA would be able to facilitate the student’s learning.

The students would not be maximizing the learning potential by just having one method [3]. The same paper also listed the average amount of information that was retained through a learning method. Only 5% of information were learned though the lecture method, 10% through reading, 20% though audiovisual, 30% through demonstration, 75% through practice by doing and 90% though actively engaging the learners in the activities.

The study also found that out of 100 percent only 30% of lecture can be understood by student, but at the same time, 70%, the students tend to forget what they have understood from the lecture. Therefore, the study found that engaging the learners in the activities retained for longer duration.

The quiz games such as 'Its's Quiz time' and Askutron Quiz Show earns about $8.19 and $14.99 for every single download. Therefore, we could see that this kind of application would make user and participants to use such apps for fun, entertainment and learning.

Most of the gaming application such as stated above, and Askutron Quiz Show was developed using C# and the infamous Unity 3D engine. The games such as Red Dead Redemption 2 and Fortnite were developed using c languages generating millions of dollars in revenue each week. Therefore, the programming language such as C++, C#, Java, Python, Lua are used in the developing games and application in the software industries.

## 3. EXISTING SYSTEM

There is no specific current system used by the college to conduct the quiz, the quiz is designed using different methods whenever it is conducted by the organizer. In the previous year, Microsoft power point was used to design the quiz. When such application is used it consumes lots of time and increases the workload of the administrator. The administrator had to create hyperlinks when framing questions and answers which consumes time. Every time the quiz is conducted, the quiz coordinator must repeatedly design the slides that requires additional assistance such as timekeeper and score marker. Therefore, quiz application is designed to replace the current system as it provides dynamic updating of the scores and sets the time automatically.

## 4. SYSTEM DESCRIPTION

The application was designed using visual studio with language C# and Microsoft SQL server as database. The application consists of two modules or components, admin and user side. On the admin side, the administrator has the privilege to add, modify and delete the quiz questions and answers. The administrator can also add different categories and participants in the database. The systems support to have the features to add question according to the categories and add or modify the number of participants based on requirements and situation.

## 5. METHODOLOGY

The Desktop Quiz Application was designed and developed using the Modern Waterfall Model. It is a sequential design process used in software development processes in which progress of the activity in the project would be flowing steadily downwards (like a waterfall). Waterfall model was used for developing the project as it is basically used for the small and medium project where there are no uncertain requirements. It was also reviewed that all the phases had to determine if the project was on the right path and monitor whether it would accomplish the aims and objectives stated in the proposal.

To meet the objectives and simplify the task, the project was carried out phase wise;

*Phase I: Requirement Gathering and Analysis*

The requirement gathering, and analysis was taken care where we gather required information for the project such as software needed to develop the application and information about previous procedures of quiz conducted in the college. The planning was done simultaneously with the requirement gathering and feasibility study.

*Phase II: System Design*

Similarly, in second phase, the system design activities such as logical design, physical design along with database design are taken care.

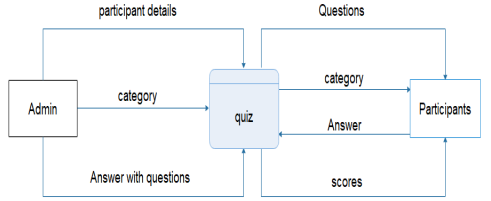



*Figure 1: Context Diagram*

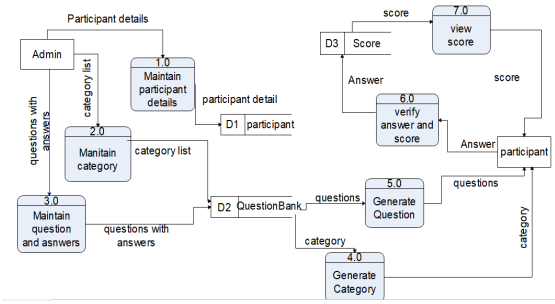



*Figure 2: Data Flow Diagram*

*Phase III: Implementation*

In this phase, the source code for the quiz application was written to meet the scope of the project. The physical design specifications for this application was converted in to the working code.

Phase IV: Integration and Testing

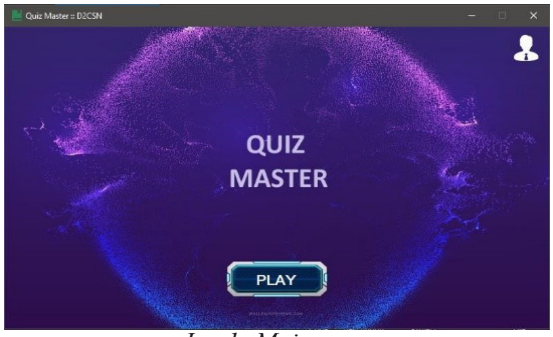
The system was tested several times before finalizing the final output. The errors encountered during the testing phase were rectified.

Phase V: Maintenance

The systems worked as expected at the moment and there may need minor maintenance if there are any issues with the compatibility in near future especially when the users migrate the QDA from one system to other.

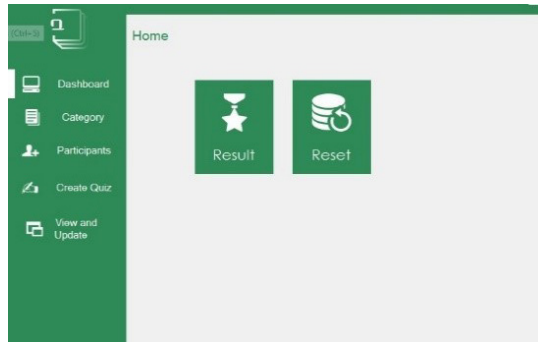
## 6. OUTCOME/RESULT

The image below is the main Graphical Interface of the QDA. The page has the play button where the user can start the quiz and at the same time, Administrator button take users to the administrator page.



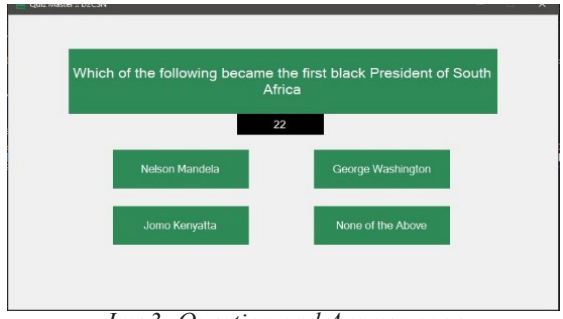

*Img1: Main page*

The image below is the Administrator page where it has the functionality such as adding, modify and deleting the quiz questions and answers, adding categories and participants, generating the quiz result report, and resetting of the quiz.




*Img2 – Administrator page*

The image below is the question and answer page where the participants can answer the questions within the given time frame. This page will also display the message to the users on their quiz attempts.




*Img3- Question and Answer page*

## 7. CONCLUSION

Quiz Desktop Application is user friendly and it can be implemented in schools and academic institution while conducting literary activities such as quiz. It can also be used as the question banks for testing the knowledge on various categories. This QDA would enhance the existing system of conducting the quiz activity in JNEC. This application system is portable, easy to manage and time saving beside interactive environment.

## 8. FUTURE SCOPE

In this application the questions cannot pass from one group to another if the questions is unanswered. In future, features like passing questions can be

added to the application.

The application does not have any platform where audience can have interactive session. In future, such features can be added to the application.

REFERENCES

[1] A. Milezynski, “Literature reveiw;Efftectiveness of the gaming in the room,” 2007. [Online]. Available: https://msu.edu>~mile zynl>artifacts.

[2] s. McLester, “Game Plan. Technology and Learning,” 2005.

[3] “Consrructivist Learning Theory,” NDT Resource Cneter, 1993.

[4] W. Royce, “Management of large software system,” 1970.

[5] IOWA State University, “Extension and outreach:What is feasibility study?,” 2013. [Online]. Available: http://www.extension.iastate.edu/agdm/wholefarm/html/c5-65.html.

[6] O. Rodney, “Feasibility Studies Made Simple,” 2007. [Online]. Available: https://tn.upi.edu/pdf/business_feasibility_study_made_simple.pdf.

[7] Tutorial Point., “Waterfall Model,” 2017. [Online]. Available: http://www.tutorialpoints.com/sdcl/sdcl waterfall_model.com.

[8] W. A. H. Y. J. P. W. Will, Ed., New Media, Knowlegde Practice and Multiliteracies . Literature rewiew: Online quiz development, Springer Singapore Heidelberg New York Dordrecht London, 2014.

[9] GEEKSFORGEEKS, “Types of Software Testing,” 2013. [Online]. Available: https://www.geeksforgeeks.org/types-software-testing/amp/.

# Comparatice Study On Manual And Electronic Tendering

Chandra Bdr. Rai[1], Manoj K. Bhattarai[2], Nima Dolma Ghishing[3], Rita Ghalley[4], Tshering Phuntsho[5], Parashuram Sharma[6], Thinley Wangmo[7]
Department of Humanities and Management,
Jigme Namgyel Engineering College, Royal University of Bhutan, Dewathang, Bhutan

*chandrabdrrai5@gmail.com[1], jonambhattarai20@gmail.com[2] 3.ghishingnima@gamil.com[4]. ghalleyrita1998@gmail.com[5]. tsheringphuntsho700@gmail.com[6]. psharma04@jnec.edu.bt[7]. thinleywangmo@jnec.edu.bt[8]*

***Abstract- Procurement is a process of acquiring goods and services. The method of procuring resources initially started with tendering process; in order to receive better goods and services. However, with the advent of sophisticated digital technology the tendering process is also made electronic. Therefore, this project aims to study the effectiveness of manual tendering process and electronic tendering process. Detail study and comparison is made between two processes by selecting a few organizations in Bhutan who have adopted electronic tendering process. Both qualitative and quantitative methods were applied in collecting data for the mentioned study. The results have showen that electronic tendering or e-tendering weighs more advantage than manual tendering.***

***Keywords—Public Procurement, Manual Tendering, Electronic Tendering***

## 1. INTRODUCTION

### A. Background

Purchasing starts where procurement ends; Procurement deals with tendering and purchasing deals with ordering goods and services.

A tender is an offer to do or perform an act which the party offering is bound to perform to the party to whom the offer is made. A tender process can be done with exchange of money or specific articles.

Manual Tendering is the procurement process where goods, work and services is procured manually using paper-work and human force unlike electronic tender where there is very limited human effort put. It is also called traditional tendering. It gave the procurement practitioners drawbacks on transparency, accountability, possibility of corruption, expensive and environmentally unfriendly in nature because of the use of paper. Further, the manual tendering creates inconveniences for the bidders located in the geographically challenged area.

Electronic Tendering is procurement process is conducted online. The users of electronic tendering (e-tendering) needs to create username and password, thereafter through the e-tendering portals they can participate in tender virtually.

### B. Problem statement

Bhutan has been following manual tendering process although it has certain drawbacks such as longer procurement cycle, expensive in nature and issues of embezzlement of tender documents where it leads to difficulty in maintaining transparency and accountability. In order to overcome such issues, Electronic Government Procurement (e-GP) system was introduced and implemented in several districts in the country. Therefore, this comparative study is carried out to see gaps between these two methods of tendering.

### C. Aims and objectives

The study aims to create awareness on the effectiveness on the electronic tendering process providing vivid difference between the two methods. This is based on the introduction and implementation of e-GP system in recently in the country. It also provides perspective from both users and non-users of electronic government procurement.

## 2. LITERATURE REVIEW

Electronic tendering is an effort to reduce corruption, improve transparency and efficiency,

and minimizing potential collusion among the bidders. The initial benefit found in the study are; reduced time and cost saving for both government and contractors, as single online portal provides all the documents and information required, eliminating the needs for in-person visits and printing cost. It also contributes in reduction of fraud and corrupt practices as there is no personal contact with bidders. In fact, when complains are received through the e-tendering, it can be cleared in a fast way [8].

Studies have identified e-tendering as the Hallmark and main concern of global e-GP. E-tendering benefits could be adequately reaped by understanding the roles of Information Technology to run the tendering procedure, considering the fact that system software and hardware makes the e-tendering easier to understand online registration of bidder. E-Tendering is a powerful tool to improve effectiveness and efficiencies as well as service quality for organizations. E-tendering system has been implemented to achieve significant benefits such as cost savings and increase in efficiency. Other advantages in applying e-tendering system are faster and higher transparency compared to traditional tendering. The system helps procuring agencies in making decision through providing easy access and relevant information about each bid and competitors. Awarding process will be very organized and precise because the committees will have better knowledge about these bids and they could obtain better contractor which will save a lot of unnecessary costs [11].

Practicing e-tendering provides quality bidding, efficient timelines, cost saving, minimizing efforts in doing business, reduce financial risks and technical risks, and finally increase competition which leads to save cost in procurement of goods or services [12].

In the year 2001 New South Wale government has implemented the e-procurement. Even they called as smart buying for government strategy. Due to the rapid development of internet technology, the New South Wale governments have found out lot of benefits by implementing e-tendering. Some of the benefits are save time and resources, drive down the cost of tendering, and higher quality goods are procured. Despite, having lots of its advantages, the government also encountered with several challenges: challenges for the management of service supply, such as facilities services, (E.g.; clearing and catering). It is difficult to manage e-procurement. In order to overcome these challenges they have installed electronic business applications: Preventive Maintenance (PM) and Enterprise Buyer Professional (EBP). With these two softwares, they are able to do better e-procurement services through e-tendering [1].

## 3. METHODOLOGY

The study is based on mixed mode approach that are qualitative and quantitative.

### *Data Collection*

Data were collected using the structured questionnaire through self-administered interviews in the Google form. The questionnaire was designed in a way that provided the spontaneous recording of response from the respondents. Questionnaire consists of 14 questions related to electronic tendering and manual tendering. In the qualitative research, face-to-face interview was conducted with the procurement section of Samdrup Jongkhar district as well as resource person from procurement department under Ministry of Economics Affairs. The mixed mode approach was applied mainly to acquire sufficient information to draw valid conclusion.

## 4. RESULT AND DISCUSSION

### A. Effectiveness of Electronic Tendering over Manual Tendering

Upon analyzing the comparative study between two process of tendering (manual and electronic), it is noted that electronic tendering has more advantage features as compared to manual tendering as follow;

1. Helps to save Gross Domestic Product (GDP)

According to Bhutan Electronic Government Procurement readiness assessment and roadmap. It states that e-GP has the potential to greatly enhance the governance of a large proportion of government expenditure each year. e-GP has increased the efficiency of RGoB's procurement administration by minimizing the cost of government supply. Experiences with e-GP in other countries show that

the resulting savings can amount to 10-20 percent or even more. Thus, for Bhutan, where government procurement equals to around 15 percent of GDP, the value of a saving of this order or even much lesser amounts would be of major budgetary and economic significance: a gain of about Nu.55 million can be expected from each 1 percent of savings in public procurement.

2. Transparency

In terms of manual tendering process, it is difficult to maintain transparency because once the tender document is submitted, there is high chance of fraudulent practices where there may be misrepresentation of data provided the PA ethically conducts the opening of bid.

On the other hand, in an electronic tendering process, there is higher transparency as it is technologically driven. Fraud and bribe can be avoided up to a great extent. According to the CPPP (Certificate Program in Public Procurement) course on unit III, under benefits of e-Procurement "Enhances transparency, uniformity compliance and integrity".

3. Time Consumption

Traditional procurement process takes longer time. It typically takes 13(Weeks) * 7(Days) = 91days. Such is in manual tendering process. Where-as in electronic tendering process, it takes lesser time than that of the manual tendering.

According to [2], "In business world, time is money, so there is more staff time involved in procurement process. Buyers can cut and paste data from the electronic tender documents for easy comparison in a spreadsheet. Manual tendering was paper and conversation based. Where-as e-tendering can be concluded quickly through online".

4. Supplier Relationship

It's difficult to expand the market place for buyers and suppliers because of limited access of the information, supplier have to physically present to register. On the other hand, e-tendering helps in expanding the marketplace for buyers which will lead to increasing contract opportunities for suppliers. Automation and streamlining of tenders, enhanced speed of supplier registration, improved cash flow due to shorter procurement cycles and payment automation.

5. Communication and Delivery of Documents

Communication between the bid opening communities and the bidder has to be done through phone call or personal meeting for delivery of documents. The geographical factors come into exist that the bid requirement cannot be made on time or some potential bidder cannot get excess to the bid opening. The web based electronic tendering help bidders to communicate and deliver the documents directly reducing the cost and time consumption.

6. Cost of Procurement Process

Cost incurred in manual tendering is found higher than electronic tendering. It is learnt that manual tendering process involves much of manual documentation such as printing in many copies, reaching to concern organisation which seems inconvenient and cost intensive whereas electronic tendering limits such inconveniences and cost.

In the case of advertisement, the rules prefer wide spread of tender notification to anticipate mass participation by the suppliers, contractors and consultants. In the country, mass media include newspaper, television and official websites of concern organisations to reach notification at large. However, flotation of tender via such mass media is also found expensive. For example, to notify tender through newspaper, it cost about Nu. 56,000 in full page, Nu.26, 000 for half page and Nu.13, 000 for one fourth page. This financial implication is also a burden for a procuring agency. If tender is floated electronically, such expenses gets minimized drastically based on the size of the file. Currently e-GP guideline 2017 has 4MB for single file size and 50MB on a total file size.

7. Reliability

The degree of errors in electronic tendering is less compared to manual tendering with auto correction or highlighted if any errors. Electronic tendering is one-time purchase and need not be purchase again and again. All the bidders are registered in electronic tender reducing the ability to cheat. In manual tendering information are less accessible by bidders. Information within the bid documents are difficult to evaluate due to lack of resources but in

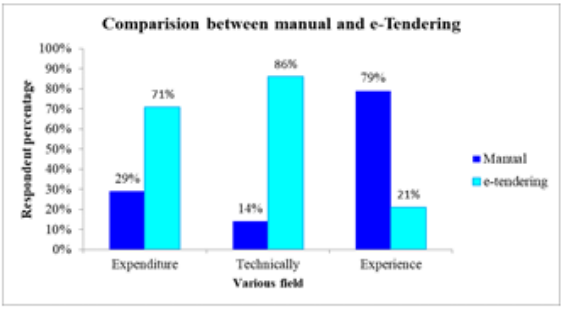
electronic tendering it is more reliable to cross check information.

B. Findings on the survey

The above figure is based on the Survey Questionnaires conducted on the manual tendering users and the practitioners of e-GP. The three categories on which manual and the electronic tendering may be compared are listed below;

1. Financial/Expenditure basis

According to the survey on the basis of finance, the




electronic tendering is comparatively less than the manual tendering. Thus, 71% respondents believe that electronic tendering is much cheaper than manual tendering in the long run but 29% still believe that electronic tendering is expensive as compared to manual tendering. The very reason for the respondent to feel that electronic tendering is expensive is due to set up cost incurred in the beginning.

2. Technical basis

As a procurement practitioner, 86% prefer electronic tendering because with right input the output is valid with transparency. On the other hand, 14% showed concern on not be able to guarantee hundred percent safe. Due to hackers, falling information into wrong hands.

3. Experience basis

The implementation of the electronic tendering in Bhutan dated on 2017 thus 79% people lack experience and training but anyway 21% concluded that they are using electronic tendering and find easier and more convenient to use.

## 5. CONCLUSION

Bhutan has been using manual tendering until the launch of electronic tendering in the form of e-GP with effect from June, 2017. The above is discussed regarding the findings on how electronic tendering is proved to be effective and efficient compared to the manual methods. In addition, views from users of the two methods were collected through interviews and survey. Findings showed that electronic tendering weighed more in advantage compared to the manual tendering method. Challenges to implement electronic tendering were found to be in the areas of change management from the management side and lack of knowledge in information technology from the practioners side. As development takes place it leads to ease in live style and does it in work. Electronic tendering has eased the work on manually done process of tendering into virtually eased work.

## 6. RECOMMENDATION AND FUTURE SCOPE

A. Recommendation

The following are the recommendations after the study;

1. Additional Training to the Procurement Practitioners

After the survey conducted and the interview with a e-GP user, it was found that a portion of the respondents of the survey were unaware of the electronic tendering being implemented in the country. The findings also show lack of knowledge on electronic tendering among the bidders. Therefore, additional training to the procurement practitioners are required.

2. Implementation of e-GP System

Implementation of e-GP system is one of the challenges every government, private and corporate organizations are facing. Additional intervention is found necessary while implementing such new system which may bring positive outcomes. Electronic tendering or the e-GP is recently implement in the country, it may take time to alter the system entirely although beneficial. Awareness maybe a solution as well.

B. Future Scope

This study is largely deficient on experience-based on e-GP knowledge. The research findings of the study may be used to expand knowledge of the Bhutanese users of electronic tendering (e-GP), may be used as a reference for the college students and to creates awareness on suitability of e-tendering.

## 7. ACKNOWLEDGMENT

The team of this project would like to pay their heartfelt gratitude to Jigme Namgyel Engineering College in providing opportunity to conduct 'Final Year Project' which has enhanced our knowledge in Procurement, tendering and related subjects. Further, as an aspiring procurement manager it has given us new insight on needs and improvement of tendering process in country Bhutan.

Guiding us to receive such productive insights is all due to our project guide Asst. Professor Mr. Parashuram Sharma under the Department of Electrical Engineering and Asst. Lecturer Ms. Thinley Wangmo under the Department of Humanities and Management. Without their guidance and support, the findings of the project would be insignificant.

Nevertheless, we appreciate the excellent team spirit our own team members have manifested. With the presence of one vision and uniform attitude towards academic works, we could complete the project with quality result.

## REFERENCES

[1] Asian Development Bank, Inter-American Developemnt Bank & The World Bank, "e-GP ROADMAP," 2006. [Ar lein]. Available: siteresources.worldbank.org/

[2] hiewliming, 11 4 2019. [Ar lein]. Available: https://www.slideshare.net/hiewliming/traditional-procurement-method .

[3] Ministry of Finance , "e-GP Guidelines," August 2017. [Ar lein]. Available: https://www.egp.gov.bt. [Cyrchwyd 7 May 2019].

[4] S. . L. Kajewski, a . A. Weippert,, 22 3 2019. [Ar lein]. Available: https://eprints.qut.edu.au/4056/.

[5]T. Udayan, 3 September 2018. [Ar lein].

[6] Asian Development Bank, "Links to Existing e-GPs," 2015-2017. [Ar lein]. Available: https://e-gp.adb.org/links-to-existing-e-gps/. [Cyrchwyd 13 May 2019].

[7] BBS, "Eletronic Government Procurment (e-GP) System launched," 22 June 2017. [Ar lein]. Available: http://www.bbs.bt/news/?p=74765. [Cyrchwyd 22 May 2019].

[8] M. Dinka a R. Migambi, "How Rwanda became the first African country with an electronic procurement system," THE WORLD BANK GROUP, 2018.

[9] Tenders.Net, "Tenders.Net; Bringing buyers and suppliers together," 1989. [Ar lein]. Available: https://tenders.net. [Cyrchwyd 21 April 2019].

[10] D. Namgay, Interviewee, [Cyfweliad]. 3 may 2019.

[11] M. N. Mohd Nawi a etal, "E-Procurement in Malaysian Construction," International Journal of

Supply Chain Management, cyfrol 6, pp. 209-213, March 2017.

[12] F. Zulhumaid a N. A. Salleh, 15 04 2019. [Ar lein]. Available: https://www.researchgate.net/publication/311389070_The_benefits_and_challenges_of_E-procurement_implementation_A_case_study_of_Malaysian_company.

[13] S. Kumar, 09 05 209. [Ar lein]. Available: https://www.slideshare.net/SandeepKumar36/etendering.

[14] Bhutan Broadcasting Service, "Electronic Government Procurement (e-GP) System lunnched - BBS," Thimphu, 2017.

[15] Ministry of Finance, "Procurement Rules and Regulations 2009," Thimphu, 2019.

# Sensors Enabled Smart Green House

Phuntsho Namgay, Tshewang Norbu, Tshering Lhamo, Yakdat Kumar Ghalley,Phuntsho Lhendup,
Srijana Gajmer[1] and Sangay Chedup[2]
Department of Electronics and Communication Engineering
Jigme Namgyel Engineering College, Royal University of Bhutan

*Email: srijanagajmer@jnec.edu.bt[1] , sangaychedup@jnec.edu.bt[2]*

***Abstract—This project presented through this paper provides an insight on how a conventional greenhouse can be evolved into a better, efficient and more, so making it smarter. Technology can revolutionize the conventional methods of farming methods, in this case greenhouse. Three important parameters temperature, humidity and moisture content required for the proper growth of plants are monitored, regulated and automatically operated using sensors enabled/controlled by arduino.***

***Keywords: Greenhouse, sensors, smart greenhouse, environment***

## 1. INTRODUCTION

Greenhouse particularly used in agriculture farming are for optimization of environmental conditions to enable the proper growth of plants [1]. The conventional greenhouse technology does not employ any smart systems nor modern technologies. A client or person are required to monitor and regulate the environmental conditions.

The conventional methods can be optimized by using modern technologies. The smart greenhouse in this paper is to optimize the environmental conditions for better growth and yield. Here sensors viz. temperature sensor, humidity sensor and moisture sensors are deployed in the greenhouse. These sensors enable the automatic monitoring, regulation of temperature, moisture content of soil without the need for manual intervention of person/client.

Optimum temperature in the greenhouse can be set depending upon the species of plants grown in greenhouse and accordingly controlled. When the temperature in the area goes beyond the optimum set temperature, also read on LCD screen, temperature sensor gets activated and exhaust fans installed will enable the drawing out of hot air and also draw-in cool air. As the temperature drops to its required level, fans would automatically go off without having a person to put off the fans. On the other hand, moisture sensor would detect the water level requirement for the plant. As the moisture level is low, sensor gets activated and motor is turned on, thereby sprinkling the water. On reaching the required soil moisture level, motor turns off automatically again without having the intervention of a person. Arduino microcontroller is used as backbone in working of this whole system. This paper is organized as follows. In section II, similar works carried out are surveyed and reviewed, the motivation for this work is explained briefly in section III. In section IV, design parameters are discussed as system design and in section V, solutions for optimizing the environmental conditions are explained as part of this work. Section VI explains the reliability and robustness of this design explained on the basis of data collected from deployment of these sensors. Section VII acknowledges the personals who contributed towards this work followed by the references.

This conference paper is a result of final year student project work carried out in partial fulfillment of Diploma in Electronics and Communication Engineering, supported by management of Jigme Namgyel Engineering College.

### *Related works*

The deployment of modern technologies in greenhouse is a growing trend. These technologies would mean automation in particular sense for enhancement of proper climatic conditions for the growth and also ensure food security and sustainability. These technologies are also often influenced by factors such as low cost of electronic components required for its implementation and the ease of control it can provide. Many studies are being

carried out by researchers to optimize the weather conditions artificially towards better food production using modern technologies.

Authors in  proposed for green house automation using zigbee and smartphone. The deployment of sensors for periodic monitoring and control of greenhouse gases in an enhanced manner is discussed in [2] as environmental monitoring and greenhouse control by distributed sensor networks. The significance of soil fertility monitoring towards ensuring better yields or production using modern technologies is discussed in [3]. Smart agriculture with deployment of IoT in [4] gives outline on how a sensor can help agriculture production. According to [5] it is essential to control the environment optimally by taking physiological status of fruits grown into condition. Intelligent control technique based on Speaking Fruit Approach (SFA) is discussed in [5].

SPA technique for intelligent greenhouse [6] discussed on speaking plant approach (SPA) where it stresses that optimal crop cultivation conditions should be based on the physiological status of plant. A control system for greenhouse using geothermal energy as power source for heating system using adaptive neuro-fuzzy inference system is proposed for design in [7]. In [8], the heat loss from the greenhouse structure as the determining factor for greenhouse heater requirements is discussed and proposed a scheme that measures the on-line sequential data of temperature from the greenhouse and heating power is recursively updated based on the energy balance of an elementary volume of greenhouse air by using intelligent controllers. Further in [9],[10] Zigbee wireless sensor networks and wireless sensor network for greenhouse monitoring and control system is proposed for design. References [11]-[14], discusses on the automation of greenhouse using IoT, android and arduino.

Considering all the related works carried out so far with regard to optimization of greenhouse environment conditions, this paper discusses on the simple technique i.e. deploy low cost, small size and reliable sensor units to optimally monitor the greenhouse conditions. Simple implementation, low cost and materials available determines the construction and development of smart greenhouse. Arduino microcontroller is found to be very handy in implementation and realization where sensors, a very basic sensors are only required to monitor the important parameters for greenhouse.  With reference to all the related works, this work is the amalgamation and improvement from the related works carried out by other authors.

## 2. PROBLEM STATEMENT

Despite many research and designs carried out for greenhouse automation, it is found to be difficult to implement in real scenario. Moreover, taking the scenario of Bhutan, agriculture farming and also greenhouse technologies in particular already in use are all conventional ones. On the other hand, to ensure food security or food sufficiency is the major milestone that is considered seriously in Bhutan. Therefore, embedding the technologies into agriculture production is found to be one way forward to achieve the national goal. This paper discusses how technologies can encourage the farmers where involvement of farmers to attend to farm works can be reduced.

The smart greenhouse which would automatically monitor and control the environmental conditions in greenhouse is taken as pilot which can be scaled up in near future. This smart greenhouse uses sensors mainly to monitor important greenhouse parameters viz. temperature, humidity and moisture where day-to-day involvement of people is not required for monitoring.

## 3. METHODOLOGY

### *System Design*

Detailed study on sensors and its incorporation with the arduino microcontroller was explored to achieve the aims and objectives of the project. Further, upon understanding the similar works carried out as per the literature reviews, context of work is drawn towards its relevancy in Bhutan.

Therefore, the system design is guided by the sequence of activities planned and carried out as represented in Figure 1.

### *Model Design*

Arduino Uno microcontroller plays centre role in overall functioning and running of sensor. AC

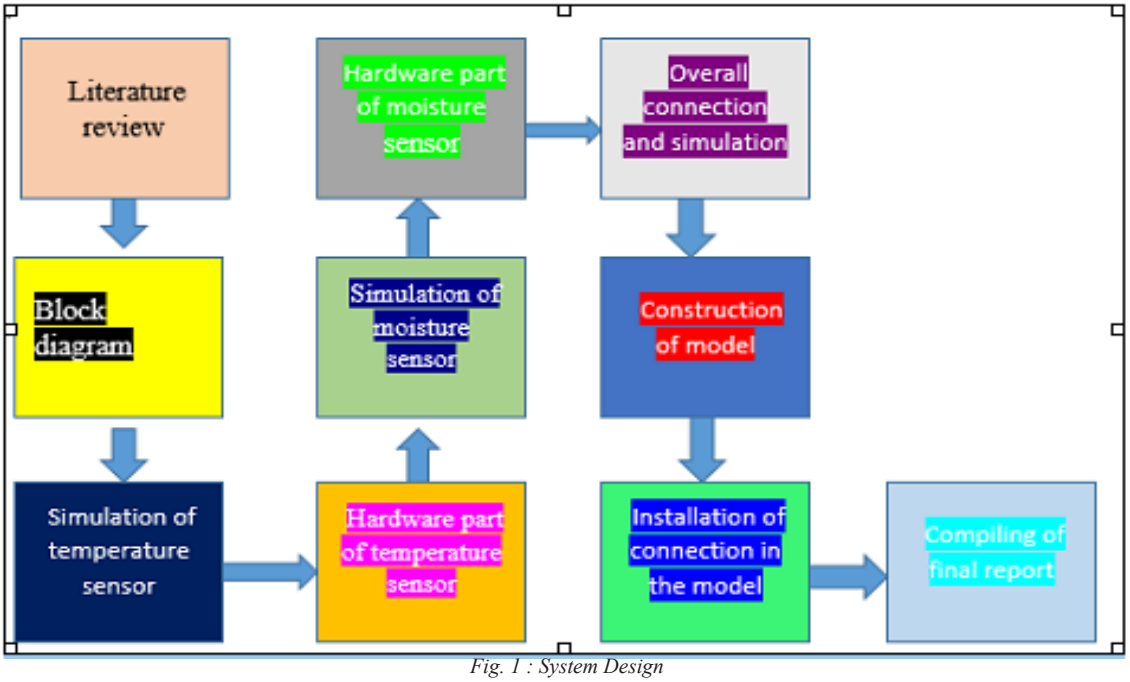



*Fig. 1 : System Design*

power, soil moisture sensor and temperature sensor (LM-35) are the input modules which feeds the data from the outside environment. The real time soil moisture content, humidity level and temperature in the greenhouse are detected by the sensors. These information/data is feed to the Arduino Figure 1: Methodology

microcontroller. Arduino is programmed setting the conditions at which output modules AC water pump motor and exhaust fans will be activated. As the temperature exceeds the maximum set greenhouse temperature, relay coil is turned ON, hence exhaust fans are turned ON to exhale the hot air, in turn reducing the temperature to its required level or below. The LCD 16 X 2 displays the real time temperature for the reference of users.

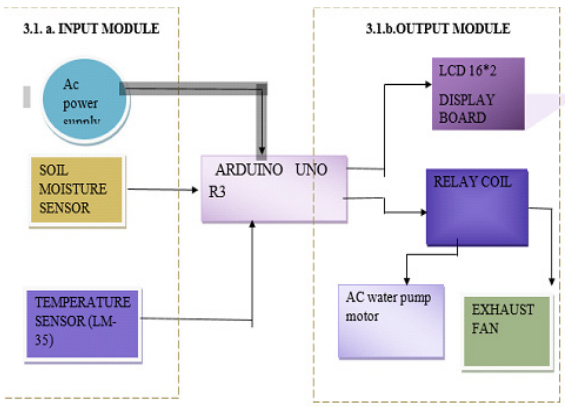



*Figure 2: Model Design*

Similarly, soil moisture sensor will enable the monitoring and control of moisture required for the plants/fruits in the greenhouse. The maximum moisture level in this case is set between 1 to 100 percent where at 60% relay coil is turned ON and hence water pump is turned ON thereby sprinkling the water. When the moisture level reads more than 60%, relay coil will be OFF, putting off the water sprinkling. The detected moisture level is displayed in LCD 16 x2 for reference as well.

## 4. RESULTS

The system is designed and tested in the virtual environment using Proteus Design Suite, student version. On consistent generation of simulation data with the sensors and components incorporated for the system design, hardware system is designed as follows.

A model of real time working system is designed and developed. Hardware devices viz. sensors and Arduino microcontroller are assembled as per the simulation results. Arduino 1.8.11, the open-source Arduino Software (IDE) is

In order to confirm the reliability of system built, data were recorded spanning over month-long observation in different time period under the influence of different weather conditions.

| ANALYSIS | SET OF DATA | | | | |
|---|---|---|---|---|---|
| Number of trails | Date (May-June month) | Set Temperature(27-30)degree Celsius | Exhaust Fan (Speed %) | Set Moisture level (0-100 %) | DC Motor |
| 1 | 6th May morning | High | ON (100%) | low | ON |
| 2 | 6th evening | 29.9 | OFF | 40% | ON |
| 3 | 7th (12:30pm) | 34 | ON (40%) | 41% | ON |
| 4 | 8th (4:30pm) | 36 | ON (47%) | 43% | ON |
| 5 | 9th (9 am) | 25 | OFF | 100% | OFF |
| 6 | 10th (8:30 am) | 27 | OFF | 95% | OFF |
| 7 | 11th (11 am) | 37 | ON (51%) | 45% | ON |
| 8 | 12th (1 pm) | 34 | ON (40%) | 41% | ON |
| 9 | 13th (3pm) | 31 | ON (36%) | 52% | ON |
| 10 | 14th (8 am) | 29 | OFF | 60% | ON |

*Table 1: Temperature Sensor and Moisture Sensor readings recorded for different conditions in greenhouse*

The recorded data in Table 1 represented the consistency and reliability of sensors deployed in the system. This represents the efficient monitoring and control of temperature and moisture level in greenhouse in particular.

However, the data presented in Table 1 is limited to the readings taken in nine days against the consistent data generated by the system over the month-long monitoring carried out. used for programming in C which interfaces sensors with the Arduino controller. The conditions for the activation of physical devices viz. motor, fans are set in the program as per the data generated by sensors deployed in the greenhouse. On meeting all the requirements for design as defined in the project scope, model is deployed.

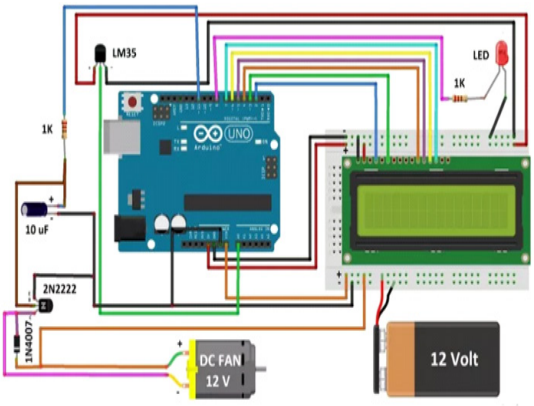



*Figure 3: System circuit in operation for the greenhouse*

The whole system as set up for the entire working of smart greenhouse enabled by sensors is represented in the figure 3. The figure represents the simulation circuit performed in proteus. A section of program written to perform the activation of sensors and accordingly display its data on LCD is also presented in figure 4.

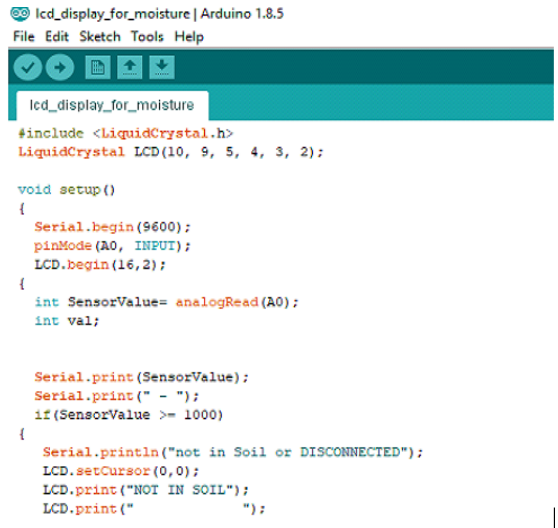



*Figure 4: Abstract program for LCD display*

## 5. CONCLUSION

This work is primary about the improvement of current agriculture farming practices by using modern technologies for better yield and to minimize the labor. This work provides a model of a smart greenhouse to help the farmers to carry out the work in a farm automatically without having to perform the monitoring and control of temperature and soil moisture level manually. Green house being a closed

structure protects the plants from extreme weather condition namely; windy, hailstorm, ultraviolet radiation and insects and the pest attack. From this project, it is learned that farming can be mechanized by application of such technologies. The deployment of sensors in agriculture farming is an alternative towards encouraging farmers to work in farms effectively. In this project, it is also realized that water resources can be used optimally by deployment of sensors.

This work in particular has been a successful test on applications of sensors in farming through deployment in greenhouse. The future works could include the scaling upto life size greenhouse deploying these technologies. The adoption of this technology can be tried in local community. Further more robust and reliable sensors which can be deployed in farming to generate even more reliable data, perform monitoring and controlling can be explored.

### *Future Scope*

Agriculture farming can be further mechanized for sustainable agriculture products using modern emerging technologies. Internet of Things (IoT) technologies with smarter and more reliable sensors can be explored and expand in the future.


### *Acknowledgment*

We would like to extend our heartfelt gratitude to the management of Jigme Namgyel Engineering College for providing us the necessary facilities for the successful completion of our work.

We would like to express our deep and sincere gratitude to our project guides Ms. Srijana Gajmer, Associate Lecturer and Mr. Sangay Chedup, Lecturer for all the necessary support throughout.

We would also like to extend our appreciation to Mr. Sangay Chedup, HoD for helping with edition and formatting of this work, Ms. Sangay Dema, Sr. Technician, Mr. Norden Wangchuk, HoD, Department of Mechanical Engineering for all the guidance, encouragement, and for all facilities to complete this project.


REFERENCES


[1] Dhumal, Y. R., and J. S. Chitode. "Green house automation using Zigbee and smart phone." International Journal of Advanced Research in Computer Science and Software Engineering Research Paper 3.5 (2013).

[2] Prabhu, SR Boselin, et al. "Environmental monitoring and greenhouse control by distributed sensor Network." International Journal of Advanced Networking and Applications 5.5 (2014): 2060.

[3] Mishra, Purvi, Sudha Mapara, and Vyas Preeti. "Testing/Monitoring of Soil Chemical Level Using Wireless Sensor Network Technology." International Journal of Application or Innovation in Engineering & Management 4.11 (2015)

[4] Rajalakshmi, P., and S. Devi Mahalakshmi. "IOT based crop-field monitoring and irrigation automation." 2016 10th International Conference on Intelligent Systems and Control (ISCO). IEEE, 2016.

[5] Morimoto, Tetsuo, and Yasushi Hashimoto. "An intelligent control for greenhouse automation, oriented by the concepts of SPA and SFA—an application to a post-harvest process." Computers and electronics in agriculture 29.1-2 (2000): 3-20.

[6] Nishina, Hiroshige. "Development of speaking plant approach technique for intelligent greenhouse." Agriculture and Agricultural Science Procedia 3 (2015): 9-13.

[7] Atia, Doaa M., and Hanaa T. El-madany. "Analysis and design of greenhouse temperature control using adaptive neuro-fuzzy inference system." Journal of Electrical Systems and Information Technology 4.1 (2017): 34-48.

[8] Revathi, S., and N. Sivakumaran. "Fuzzy based temperature control of greenhouse." IFAC-PapersOnLine 49.1 (2016): 549-554.

[9] Zhou, Yiming, et al. "A design of greenhouse monitoring & control system based on ZigBee wireless sensor network." 2007 International Conference on Wireless Communications, Networking and Mobile Computing. IEEE, 2007.

[10] Ahonen, Teemu, Reino Virrankoski, and

Mohammed Elmusrati. "Greenhouse monitoring with wireless sensor network." 2008 IEEE/ASME International Conference on Mechtronic and Embedded Systems and Applications. IEEE, 2008.

[11] Vatari, Sheetal, Aarti Bakshi, and Tanvi Thakur. "Green house by using IOT and cloud computing." 2016 IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT). IEEE, 2016.

[12] Shirsath, D. O., et al. "IoT based smart greenhouse automation using Arduino." Int. J. Innov. Res. Comput. Sci. Technol 5.2 (2017): 234-238.

[13] Teslyuk, Taras, et al. "Automated control system for arduino and android based intelligent greenhouse." 2015 XI International Conference on Perspective Technologies and Methods in MEMS Design (MEMSTECH). IEEE, 2015.

[14] Enokela, Jonathan A., and Theophilus O. Othoigbe. "An automated greenhouse control system using Arduino prototyping platform." Australian Journal of Engineering Research 1.1 (2015): 64-73.

[15] Baviskar, Jaypal, et al. "Real time monitoring and control system for green house based on 802.15. 4 wireless sensor network." 2014 Fourth International Conference on Communication Systems and Network Technologies. IEEE, 2014.

[16] Bajer, Lukas, and Ondrej Krejcar. "Design and realization of low cost control for greenhouse environment with remote control." IFAC-PapersOnLine 48.4 (2015): 368-373.


JIGME NAMGYEL ENGINEERING COLLEGE
ROYAL UNIVERSITY OF BHUTAN

## OUR VISION

A premier Institute of applied engineering, management and technology towards developing highly competent and innovative technical personnel infused with the values of Gross National Happiness.

## OUR MISSION

- To provide quality education, driven by GNH values, in the field of applied engineering, management and technology that are current and beneficial to individuals, employers and the nation;
- To provide resourceful services through professional development training, consultancy and expert services;
- To conduct research & innovation in relevant areas; and
- To develop active linkages with organizations and academic institutions both within and outside the country.

ISBN : 978-99936-986-3-0

9 789993 698630

Author & Publisher:
Jigme Namgyel Engineering College