

# JNEC Thruel Rig Sar Toed দ্র্মে মিশাশাশ্বন শার্চিন।

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## Foreword

Jigme Namgyel Engineering College has come a long way in its endeavor to provide quality technical education in the field of applied engineering from its initial establishment as Royal Bhutan Polytechnic in Dewathang to Royal Bhutan Institute of Technology in Kharbandi, Phuentsholing and the institute later continued as Jigme Namgyel Polytechnic back at Dewathang in 2006 and finally renamed as Jigme Namgyel Engineering College with the introduction of bachelor's programme in 2015.

Over the last 47 years of its service, JNEC has grown tremendously, in terms of infrastructures, facilities, innovations, linkages and the programmes it offers today. Nevertheless, its mission to provide quality higher education and foster research and innovation culture in the relevant areas are progressing gradually. This is evident from the increasing number of projects and research activities that staff and students have carried out over the last few years. Some of the selected research papers are presented in this volume of "Thrue Rig Sar Toed - Academic Excellence through Research and Innovation". The selected papers represent scholarly excellence achieved by the students in the midst of COVID-19 pandemic.

We believe that sharing, disseminating and exchanging of experience and knowledge is an essential means to facilitate an in-depth dialogue and synergistic collaboration between the colleges and stakeholders. It is our hope that the stakeholders would continue to support and collaborate on rigorous research on emerging issues now and in the future. As in the past, we solicit continued support from all our readers to help us to disseminate the knowledge to a larger audience.

Happy Reading.

Tashi Delek!

Dr. Tshewang Lhendup

( President, JNEC)

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## DESIGN AND SIMULATION OF DUAL BAND mmWAVE PATCH ARRAY ANTENNA FOR 5G COMMUNICATION SYSTEMS

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Abstract— Currently, the smartphones are gaining more and more popularity, due to their increasing demand for higher bandwidth and higher data rates. The exponential growth of the population has caused telecommunication sector to meet the requirements to achieve multiband operation and improve the radio signal transmission performances. In Bhutan, 5G is expected to launch from 2022. The ongoing pandemic has made us realize the impact of better connectivity through technology. There are still some challenges that cannot be accommodated even by 4G, such as the spectrum crisis and high energy consumption. Miniaturization and multi-cell array antennas in 5G offer the possibility of high-speed data transmission but pose challenges for cell phone antenna designs.

As, it has been known that multiple-input multipleoutput (MIMO) operation can effectively increase the spectrum efficiency or channel capacity, thus, the applying of MIMO technology into a smartphone will ensure the enhancement of its channel capacity. A Dual band mm Wave slotted patch array antenna for the 5G communication is proposed in this paper. The proposed antenna is operating at LTE bands 24-30GHz and 30-40 GHz. The antenna can be used in mobile phones as well as in Base stations. The bandwidth, gain, directivity, reflection coefficient and VSWR will be studied for the antenna to meet the 5G capabilities.

## Keywords—5G, MIMO, Patch antenna, Array antenna, Dual band, mm Wave, beam steering.

#### 1. INTRODUCTION

In the last few decades, economic and social development is greatly influenced by the advancement in the field of mobile communication. Having gone through the four major wireless evolution that are 1G, 2G, 3G and current generation 4G wireless mobile communication. But due to increase in demand services and increase in data usage to provides efficient system capacity, it lets to evolution of new mobile communication and elimination of antennas for mobile phone in the 1990s. Even though the current 4G wireless cellular system provide sufficient services, however there are concern about whether the current 4G will be able to sustain the increasing demand in data usage after few years. The current 4G provide services in the speed of 10Gbps and some drawback of the present cellular system include low latency, speed, capacity, battery consumption and reliability. Therefore, it lets to development of the fifth-generation cellular system popularly known as 5G. [1-2,6]

For the cellular system, different antennas are used for wireless cellular communication such as micro-strip patch antenna, slot antenna and more over array of antenna is used in 5G for transmitting and receiving information for MIMO technology [7]. MIMO technology gives the strong relative impact to 5G wireless communication system due to its benefits in terms of performance improvements with respect to Omni- directional antennas. The reason behind using these antennas array for 5G communication is that 5G operate in the band of millimeter wave, which is between the frequency range of 24 to 300GHz with a frequency band width of 250MHz. So, due to the high frequency the antenna size should be small and it is also mostly applicable in the devices such as smartphone [11]. The array of antenna can be in various size and usually it operates in very high frequency as compare to the other antenna. Due to introduction of the MIMO array antenna in 5G communication, the principle of diversity plays an important role in tackling the multi-path effect, low latency, high speed data rates and so on. Diversity means introduction of the multiple links in wireless communication.

In the contest of 5G communication mostly in the smartphone, matrix of array of antenna are used to create the multiple paths between the transmitter and receiver. These features of 5G antenna mainly miniaturization, multi –cell matrix array antenna and the beam steering technology is used in the 5G communication, where it is achieved by changing the phase of the input signal on all radiating elements. Phase shifting allows the signal to be targeted at a specific receiver which results in increase in speed, latency reduction, higher reliability, capacity and flexibility of the system [5].

As smartphone and other mobile communication devices continue to become more ergonomic and multifunctional, antenna miniaturization for 5G at millimeter wave is very important for maximizing the MIMO channel capacity. Therefore, to design the 5G mm wave antenna, some of the parameters that should be studied are size of antenna, types of substrate, antenna integration, feeding technique and compatibility with the existing 5G technology. However, to do implementation at device level it gives additional complexity and uncertainties at first stage of development, but we have to design an antenna for 5G wireless where we will be establishing the coherent for replicable placement to minimize antenna certainties and also other parameter such as mobile phone design material must also be considered [14]. It is also important to consider the ground plane dimension of the phone, frequency, wavelength, distance between the antennas and antenna miniaturization technique to support multiresonant antenna design to flexibly accommodate ongoing 5G evolution across different region [8]. So, this project aimed to provide comprehensive and holistic study in designing of 5G mm wave antenna which is applicable for the smart phone application.

### 2. MICROSTRIP ANTENNA AND ITS ARRAY

#### 2.1. Microstrip antenna

A Microstrip patch antenna, in its most basic form, consists of a radiating patch built on a dielectric substrate with the substrate attached to the ground plane as shown in Figure 1. It is a low-profile antenna with a variety of advantages over other antennas, including being lightweight, low-cost, and having more gain. The patch is usually made of conductive metals like copper or gold and can be made into any shape. In this paper the proposed slotted patch antenna is of rectangular shape. The patch is made of copper. The patch antenna's size and operating frequency are inversely proportional. This feature boosted its popularity, especially in 5G wireless communication applications where the frequency bands are extremely wide (in Giga Hertz). As a result, the antenna is of a modest scale (in millimeter). The rectangular slot is created on the patch to increase gain and directivity. The dual band can also be created by using slotted patch antenna.



around plane





Figure 2: Cooperate feeding technique

#### 2.2. Array of antenna

Single-element antennas have a broad range of radiation patterns. This indicates that they have a poor directivity. Increase in the size of the single-element antenna can improve directivity. The assembly of radiating components in a suitable electrical and geometrical arrangement to form an antenna array which is another way to improve directivity. An antenna array is a group of singleantenna components that are linked together and function as a single antenna. The antenna gain and directivity are two important factors to consider. By joining the elements of antenna array, fabrication is simpler. Antenna arrays come in a variety of shapes and sizes, depending on the application [13]. In this paper, the proposed antenna is 2x2 slotted patch array antenna.

#### 3. ANTENNA FEEDING TECHNIQUE

Different feeding strategies are used in the patch antenna array's delivery feeding network. There are a variety of methods for feeding the microstrip antenna. Such as contacting and noncontacting approaches. The contacting group denotes direct interaction between the feed line and the radiating patch [14]. In these proposed papers the feed technique used is Corporate Feeding which is the widely and most common feeding technique for fabricating antenna arrays is a corporate feed. It is the type of feeding technique where incident power is divided and distributed evenly to the individual antenna elements as shown in Figure 2.

#### 4. DESIGN PARAMETERS AND CONSID-ERATION

Duroid was used to construct the substrate which has a dielectric constant  $\varepsilon_r$  of 2.2.  $f_o$  is the operating frequency,  $z_i$  is the input impedance and t is the thickness of patch. To calculate the dimensions of patch antenna, following equations were used:

Width of the patch: 
$$W = \frac{c}{2f_o \sqrt{\frac{\epsilon_F + 1}{2}}}$$
 (1)

Effective dielectric constant of the substrate:

$$\varepsilon ff = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2} \left[ \frac{1}{\sqrt{1 + 12\left(\frac{h}{w}\right)}} \right]$$
(2)

Actual length of the patch:

$$L = \frac{c}{2f_o\sqrt{\varepsilon f f}} - 0.824h \left[ \frac{(\varepsilon_{eff+0.3}) \left(\frac{w}{h} + 0.286\right)}{(\varepsilon_{ff-0.258}) \left(\frac{w}{h} + 0.8\right)} \right]$$

Height of substrate:  $H_s = \frac{0.3c}{2\pi\sqrt{\epsilon_r}f_o}$ 

Length of Feed Line:

$$\lambda_o = \frac{c}{f_o} \tag{5}$$

$$L_f = \frac{\lambda_o}{4\sqrt{\varepsilon_r}} \tag{6}$$

Width of micro strip feedline:

$$w_f = \frac{7.98h}{e^{\left(z_i \frac{\sqrt{c_r + 1.41}}{87}\right)}} - 1.25t$$
(7)

#### 4.1. Case study

A comparative study was done by changing the dimension of the slot since it is the one of the important design parameters in antenna which increases the overall performance characteristics of the antenna. In this paper, we took dimension of the slot as  $2mm \times 0.5mm$  as it has reasonable performance in terms of its returns loss and directivity as compared to another dimension of the slot as seen in Table 1.

he comparative analysis in terms of bandwidth,

Table 1: Effect changing dimension of the slot.

Sl. no	Size(mm)		Return	Directivity(dB)	Bandwidth
	Width x length	Gain(dB)	loss(dB)		(GHz)
1	1.5x0.5	7.12	-15.671	7.09	2.865
2	2x0.5	6.94	-17.426	7.24	3.105
3	3x1	6.25	-22	6.25	3.925
4	4x1.2	7.65	-18.759	5.96	4.37

The comparative analysis in terms of bandwidth, directivity, return loss, VSWR and gain was done by changing the thickness of the substrate using Roger RT Duroid. From the analysis shown in Table 2, we can conclude that increase in frequency reduces the size of the patch and thickness of the substrate. With decrease in height of substrate, directivity tend to increase but return loss tend to increase.

Table 2: Changing height of the substrate

	Sl.no	Frequency	Size of	Height	Bandwidth	Directivity	Return	VSWR	Gain(dB)
		(GHz)	patch	of	(GHz)	(dB)	loss(dB)		
(2)		Ì,	(mm)	Substrate	Ì.				
(-)			(L x W)	(mm)					
	1	28	4.232x3.375	0.3449	3.812	4.09	-14.966	4.5578	4.27
	2	38	3.591x2.886	0.291	2.21	6.81	-13.77	3.34	6.34
(3)	3	40	2.963x2.382	0.241	1.404	8.2	-12.138	1.614	8.2
	4	60	2.963x2.438	0.1609	1.93	8.07	-15.659	37.258	3.39
(4)	5	80	1.481x1.191	0.1207	2.12	8.72	-11.58	94.85	5.29
()	6	100	1.205x0.952	0.0966	2.393	8.13	-10.629	2.1424	8.13

Table 3: Dimensions of the patch antenna for the simulation.

SI.NO	Parameter	Values (mm)
1	Length of the ground	5.774
2	Width of the ground	7.942
3	Width of patch	3.971
4	Length of patch	2.887
5	Height of substrate	0.251
6	Gap	0.05
7	Length of feedline	1.532
8	Width of feedline	0.816
9	Width of slot	2
10	Length of slot	0.5

#### 5. SIMULATION AND RESULTS

#### 5.1. Design of antenna structure

All the dimensions of the patch are given in Table

3. The construction started with a simple microstrip







antenna

slot antenna and the rectangular slot was added on the patch. In order to improve the antenna efficiency, two elements were used in array, one with the same dimensions as the other. The power divider measures 12 mm in length and 1 mm in width. The distance between the feed line's centers is 24 mm. 2x2 antenna patch array was built to further increase directivity and gain. The dimensions are given in Figure 7.



Figure 6: Slotted 2 X 2 antenna array design



Figure 7: Dimension of 2X2 antenna array

#### 5.2. Performance analysis

5.2.1. Gain

Antenna gain refers to the amount of signal a given antenna will send or receive in a given direction. Gain is determined by comparing the antenna's measured power transmitted or received in a specific direction to the power transmitted or received by a hypothetical ideal antenna in the same situation. The maximum effectiveness with which the antenna can radiate the power transmitted to it by the transmitter towards a target is measured by antenna gain. The gain is calculated for the 1X1, 1X2 and 2X2 array. 2x2 antenna has the highest gain. The results are tabulated in table 4.

#### 5.2.2. Directivity

The degree to which the radiation emitted is concentrated in a single direction is measured by directivity, a parameter of an antenna or optical device. It compares the power density radiated by an ideal isotropic radiator (which emits equally in all directions) radiating the same total power to the power density radiated by an antenna in the direction of its highest emission. The directivity of the 1X1, 1X2 and 2X2. 2x2 antenna has the highest directivity. The results are tabulated in table 4.

#### 5.2.3 Bandwidth

Another significant antenna parameter is bandwidth. The spectrum of frequencies over which the antenna can correctly radiate or absorb energy is referred to as bandwidth. The optimal bandwidth is often one of the deciding factors when selecting an antenna. Here we design the array of different antenna and compare its bandwidth. The following table show the comparative result.

Table 4: Gain, Directivity and Bandwidth of designed antenna

-				
Antenna	Gain(dB)	Directivity(dB)	Bandwidth	Return
			(GHz)	loss (dBi)
Patch antenna without	5.19	5.19	2.003	-16.01
slot				
Patch antenna with slot	6.71	7.14	1.14113	-42.28
1x2 patch antenna array	11.5	11.5	0.733	-9.850
without slot				
1x2 patch antenna array	11.6	11.9	0.65	-16.57
with slot				
2x2 patch antenna array	12.7	12.6	0.12	-31.1
with slot				

#### 5.2.3 Radiation pattern

The Radiation pattern of an antenna represents





Figure 10: Polar radiation pattern of 2x2 array antenna the energy radiated by the antenna. Radiation Patterns are diagrammatical and graphical representations of radiated energy distribution in space as a function of direction.

#### 5.2.4. Return loss

Return loss is the measure of the how well devices or line are matched. A matched is good if the return loss is high. Different system utilizes the different acceptable return loss limit, but in our case, we consider the acceptable limits of 10dBi, which means that if the return loss is below this limit, 90 % of the input power will be transmitted from the antenna.

#### 5.2.5. VSWR

VSWR stand for Voltage Standing Wave Ratio. It is the measure of how efficiently the radio frequency power is transmitted from the power source through the transmission line into the load. In the ideal case, 100% of the energy is transmitted. This requires an exact matching between the source impedance, the characteristics impedance of the transmission line. In the real system, mismatched impedance cause some of the power to be reflected backward to the source and these lets to the destructive interference. VSWR measure of these voltage variances.





Figure 9: Polar Radiation pattern of 1x2 patch array antenna



Figure 11:Radiation pattern of of 2x2 array antenna



Figure 13: VSWR for 2x2 array antenna

#### 5.2.6. S-parameter

S-parameter describe the input-output relationship between the ports (or terminal) in the electrical system. Literally means, it represents the power transferred from Port M to Port N in a multiport network. S-parameter stand for scattering parameter are used to characterize electrical networks using the matched impedance. Where scattering refers to the way travelling current or voltages are affected when they meet the discontinuity in the transmission line.



Figure 14: S-parameter for slotted single patch antenna

Figure 12: VSWR for 1x2 array antenna



50 Figure 16:S-parameter for 2x2 array antenna

60

40

#### 6. CONCLUSION

-30

-35 -40

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In this paper, the slotted microstrip patch antenna with an array with different number of patch element for the mm Wave dual band patch antenna for 5G communication has been studied. The different arrays of patch antenna design above that are 1x1 antenna with slot and with slot, 1x2 patch antenna array with and without slot and 2x2 patch antenna array with slot operates in the frequency range of 28GHz and 38 GHz in mm Wave communication which falls under

the FR-2 frequency band is presented in the paper. Return loss up to -31dBi is achieved with the gain of 12.7 dBi and 12.6 dBi directivity. The compact 5G antenna has been designed, that can be used in mobile stations and base stations. For further improvement of performance of the antenna or to fulfill the requirement of the 5G antenna, the designed antenna can be further extended for massive MIMO purposes to 4x4 or 6x4 array. That will lead to beam steering technique which lets to further improvement in the gain up to 80.4dBi with directivity up to 11.9dBi.

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#### Empirical Assessment of Evapotranspiration (ET) using Turc method in Kulong Chhu basin, Bhutan.

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Abstract— Evapotranspiration (ET) rate has not been determined in all the places within the country, Bhutan. Not all the places have complete information about the loss of water from the land surfaces (soil and vegetation) and water bodies. This results in less knowledge about the irrigation of the crop, precipitation and hydrologic cycle. The aim of this project is to estimate the daily ET of each elevation band for the year 2020 within the Kulong Chhu basin. The ET calculation is based on the TURC method (1961) that uses the least parameters under the humid condition. DEM of 30m resolution obtained from the USGS was used to extract and mask the area of interest. The study area DEM has been used to classify the elevation into different band based on equal interval. The daily mean temperature (Tmean) and relative humidity (RH) obtained from NCHM and solar radiations (RG) from PADS have been interpolated within the study. These raster data (RH, Tmean and RG) have been masked using each elevation band and calculated the average value for each band. Hence these average values of RH, Tmean and RG were used to calculate the daily ET of each band. A graph of each elevation band versus its ET has been plotted to compare the ET for different elevation band. The annual ET in Kulong Chhu basin was estimated to be 395.633mm/year.

## *Keywords—ET, Turc method, Elevation band, DEM*

#### 1. INTRODUCTION

Bhutan is highly vulnerable to the adverse impacts of climatic change [1]. The country has been facing some impacts of climate change such as crop loss to erratic rainfalls, windstorm, hailstorms, droughts and flash floods [2]. To facilitate such impacts, the knowledge of evapotranspiration is very important as the ET data is used to tackle the issues related to the water and the climate change. Evapotranspiration is the loss of water in the form of

vapor from the water and land surface (evaporation) and from the living plants (transpiration) from the stomata opening during photosynthesis. ET plays a vital role in assessing so many problems related to scarce of water especially in arid and semiarid regions. The ET values are essential in hydrological modelling, drought assessment, agricultural irrigation management, in water balance and so on. Without ET values those assessments cannot be carried out so the assessment of ET is must, prior to such assessment.

To compute ET, FAO-PM method is the globally accepted standard method ensuring the most reliable results [3]. But in some places like Bhutan, some data were not available to perform PM method. In such cases empirical methods such as Turc, Hargreaves, Priestly-Taylor and so on are used which provide the results that are comparable to PM method. The area of Kulong Chhu basin is the study area where this project is determined to assess ET using Turc method (radiation-based method).

Among the several methods approached to find alternatives to PM method carried out in Northeast regions of India, Turc method gives results comparable with the P-M method and it was observed the best suitable option to P-M method[4]. In Bhutan, the empirical equation was used to compute ET and compared against ET value by the Penman Monteith method [3]. So, we can use empirical methods like Turc method to compute ET consisting parameters like relative humidity and temperature which are available from NCHM.

Evapotranspiration is a significant component taking part in the climate change and must know the variation of ET value in particular places. ET is important in hydrological modeling, drought assessment and water depletion from the ground. However, the value or the variation of ET in Trashi Yantse is not determined till now. In order to do further research based on water depletion and climatic conditions the value of ET is must. Therefore, the purpose of this project is to estimate the daily ET for the area of interest for the year 2020 using Turc method. It is very important to estimate the water requirements for agricultural and so the ET. Estimating ET and water scarce is important for irrigation monitoring and drought assessment [5]. Though the Turc equation gives unreliable result with adjusted equation and less parameter,the calibrated one gives reliable ET value as that of P-M method as well as better results [6].

The ET was determined by comparing P-M method, Turc method and Makkink method and Turc method gives the lowest ETO value. However, in the case of limited data, Turc method is mostly used to calculate ET [7].

The compromise and grouping decision making method was used to rank 31 empirical ETO model based on four statistical metrics and found that P-M method gives good result in estimation of ETO. Nevertheless, Turc method also give similar result [8].

The model was established to predict evapotranspiration (ET) and water balance and test the linkage to vegetation and land cover using meteorological data. The calibrated Hargreaves (H) equation was used to compute ET and compared ET value against Penman Monteith method [3].

However to identify the suitable alternative to the FAO-56 Penman-Monteith equation to calculate reference ETO from chosen temperature and radiation base models among the several methods approached, Turc method gives results comparable with the P-M method and it was observed the best suitable option to P-M method [4].

Using remotely sensed solar radiation evapotranspiration was estimated and methods used are the FAO P-M method and several empirical methods like Hargreaves, Turc and Priestly-Taylor method. At last, the results from those empirical methods were also compared with the P-M method and Turc method give the reliable result [9].

Monthly ET model was established using novel hybrid machine at Ranichauri (India) and at Dar El Beida (Algeria) station. The evaluation provides better estimates at both the station using Turc method [10].

[11] Compared the evapotranspiration results

from the rain-fed grass in central Serbia, using six empirical methods against Penman-Moneith method and reported Turc produce ultimate result. The result provides a reference tool that offers concrete guidance which method to select based on available data and consistence estimates of monthly evapotranspiration.

To estimate daily reference crop evapotranspiration model using different empirical model the result showed that PM method is efficient for humid climate while others overestimate and underestimate the ETO whereas Turc method is alternative to P-M method as it requires scarce of data work best in the absence of P-M method [12].

To examine the accuracy of the classification, ground truth verification was carryout. ArcGIS was used to produce land use/cover and also remote sensing technique was used to examine data [13]. Monthly change in ET in Boston lake basin was influence by rainfall, temperature and vegetations. ET was impact by land use/cover type that is the daily ET was higher near the mountain area and lower at unused land [14].

According to Thomas, (2015) P-M method are the only reliable estimation of ET in mountain regions and temperature-based estimate such as Thornthwaite or Hargreaves are extremely not appropriate/reliable particularly in mountain regions whereas radiation based method best for this studied.

The reduced set P-M method and Hargreaves equation overestimate reference evapotranspiration while Turc equation neither overestimate underestimate. Moreover. equation nor Turc recommended for estimating reference is evapotranspiration in the absence of calibrated methods [16]

Different method was performed to predict the actual evapotranspiration of potato crop in semi-arid environment. The result show that P-M method over predict actual evapotranspiration. Whereas Turc, Priestly Taly, Makkink obtained more appropriate results for this particular area [17].

Three radiation-based method and temperaturebased method was performed to estimate ET and to project future change against P-M method. From radiation-based method Makkinki method give best result. Although other method performed best but Turc method is easy to use as it requires three parameters to estimate ET. From temperature-based method Thornthwaite method was found best for projecting future change [18].

In order to determine relation between different reference evapotranspiration estimation method and standard P-M method, the equation is compared and calibrated against P-M method. It was found that Turc, Blaney Criddle FAO24 and Regression method gives the best result based upon all statistical criteria. Thus, these methods are reliable and recommended in the studied region. While other method after calibration though it gives satisfactory result but less reliable than other best method [19]..

The four models such as Makkink, Turc, Priestley Taylor and Hargreaves were used to estimate ET with limited data. In various climate. Turc model was considered best to estimate ET in cold humid. The Hargreaves model under warm humid and semi-arid climatic condition give best results vice versa. Makkink model perform worst in all climate except for cold humid condition. However, Turc and Hargreaves showed accurate ET value [20]. Due to lowest RMSD, Turc equation give most reliable ET value at humid condition [21].

Therefore, this project estimates the daily ET value using Turc's method with limited parameters such as solar radiation, temperature and relative humidity. The ET estimation is based on the categorized elevation band within the study area for the year 2020. The end result also derived a relation between estimated ET value and elevation band.

#### 2. DATA AND METHODS

#### 2.1. Study area

The eastern Dzongkhag, Trashi Yangtse is located in the sub-tropical and alpine forest consisting of rich natural resources and vegetation. The majority of the area is occupied by the Kulong Chu basin with a computed area of 1526km2. The computed stream length of 82.5112km Kulong Chhu runs approximately from an elevation of 3691m to the river mouth of Drangme chhu. With the majority coverage of watershed by Kulong Chhu, its tributaries from different location aids in agricultural farming and other human activities. The

annual average minimum and maximum rainfall for the year 2020 were approximately 453.614 mm and 1750.18 mm respectively. From the LULC chart, the area is covered by the maximum of forest followed by the shrubs/meadows. The agriculture land aids up to 1.57% of the total area with 2110.60 hectares of dry land and 949.30 hectares of wet land. The snow and glacier cover up to 12.47% of the total area. The extracted minimum elevation of the study area from the DEM varies from 818.03m to 5733.12m.



Figure 1: Kulong Chhu basin



Figure 2: LULC chart of KUlong Chhu basin

#### 2.2. Data availability

The data such as daily maximum and minimum temperature and relative humidity (RH) of 11 stations were obtained from National Center for Hydrology and Meteorology (NCHM). The minimum and maximum temperature was used to obtain the mean temperature ( $T_{mean}$ ) for each station. Furthermore, the solar radiation data (RG) was downloaded from the https://power.larc.nasa.gov/data-accessviewer/ which had 20 grid points with provided

coordinates. The Digital Elevation Model (DEM) was downloaded from the https://earthexplorer.usgs. gov/. The resolution of the DEM downloaded from the United States Geological Survey (USGS) was 30m.The basin for the study area was delineated from the DEM using GIS. After obtaining the basin, the DEM for the study area was also extracted from the USGS DEM using the basin of study area.

#### 2.3. Preparation of Elevation band

The objective of this study is to estimate the daily average *ET* from each elevation band; therefore, the DEM was categorized into five elevation band with an equal interval which is as shown in the figure 3. The minimum and maximum elevation of Kulong Chhu basin is from 818.04m and 5733m respectively. The main requirement was the shapefile of each band that can be used to clip the raster data of the ET factors ( $R_{G}$ , RH and Temp).



Figure 3: Elevation band

#### 2.4. Preparation of raster data

Evapotranspiration depends on several factors such as solar radiation, air temperature and humidity. In this project, the daily *ET* rate of each elevation band was determined using the limited data such as solar radiation ( $R_G$ ), mean temperature ( $T_{mean}$ ) and relative humidity (RH). Using the 11 meteorological stations, the daily data for  $T_{mean}$  and RH were used to create a raster data for daily frequency for the year 2020. The Inverse Distance Weighted (IDW) technique was used for interpolating the data into raster data in GIS. Similarly, the daily RG data was also interpolated to raster data for daily frequency for the year 2020. The raster data were masked using the shapefile of Kulong Chhu basin. Using the elevation bands, the raster data are clipped into different bands. The average value for all the parameters (RG, RH and  $T_{mean}$ ) from each clipped raster was computed. The same process was carried out for all the daily raster data for the year 2020.

#### 2.5. Estimating ET using Turc Method

Turc method was adopted for the determination of ET for those places which had a limited climatic data. This method requires fewer data such as solar radiation, temperature and relative humidity.

$$ET = \alpha C (Rg + b) \left(\frac{Tm}{Tm + 15}\right) \quad for RH < 50\% \tag{1}$$

$$C = 1 + \left(\frac{30^{\circ} \text{ M}}{70}\right) \tag{2}$$

$$ET = a(Rg + b) for RH \ge 50\%$$
(3)

$$C=1$$
 (4)

Where, *a* and *b* are empirical constants with a = 0.31 m2MJ-1,  $b = 2.094 \text{ MJm}^2\text{day}^1$ , ET is in mmday<sup>1</sup>, T is in <sup>0</sup>C, R<sub>G</sub> in MJ m<sup>2</sup>day<sup>1</sup> and RH in %.

The average value for each parameter (RH,  $T_{mean}$ , and  $R_G$ ) was extracted from each elevation band at a daily frequency and subsequently was used to calculate the *ET* using equation 1 and equation 3. The data was further aggregated into monthly and seasonal estimates.

#### 3. RESULTS

Evapotranspiration calculated by the Turc method gave an average of ET of 2.59mm/day for the entire elevations band, on average (Fig 4 and 5) and in the table 1. For daily *ET*, maximum ET 5.118 mm/day was observed in the highest elevation (4750.01-5733m) on the 26<sup>th</sup> August and minimum ET 0.385 mm/day on 31st August in the elevation (1801.05-2784m).



Figure 4: Daily ET

Regions with the highest elevations (4750.01-5733m) observed the highest ET in the month of August and the lowest in the month of January. Regions at the lowest elevation (818.03-1801m) at the month of November observed the highest ET and lowest in January. For the entire elevation band, the maximum ET was observed in the month of August due to high rate of solar radiation and temperature.

Table 1	Statistics	of daily	ΕT	for	each	elevation
		hand				

Elevation(m)	Max	Min	SD	Mean
818.03-1801	5.076	0.386	0.858	2.633
1801.05-2784	5.047	0.385	0.803	2.520
2784.06-3767	5.079	0.387	0.807	2.554
3767.08-4750.1	5.093	0.386	0.801	2.603
4750.01-5733	5.118	0.387	0.793	2.661



Figure 5: (a) Monthly ET(b) Monthly mean ET

The study by [3] found that ET calculated by PM method yielded average daily ET of 2.6mm/day for 15 stations and monthly ET of 40-150 mm/month. Further it Hargreaves Equation was optimized for eight station with RMSE (0.586), MBE (-0.008) and R2 also validated with observed data with RMSE (0.607), MBE (0.057), R2(0.58). Although the current study could not validate the Turc's method, the results are in consisten t with the previous study. The Turc method uses Temperature and solar radiation as the determining variables.

The Turc method uses temperature and solar radiation as the determining variables. It has shown that ET is increasing at given temperature and radiation with decrease in relative humidity below 50%. At higher relative humidity (RH>50) ET is mainly driven by radiation and temperature and RH does not have an impact.

A box plot was also used to dervive the information on the maximum, minimum, median, mean (marked by ×), outlier points, upper and lower quartile of monthly and daily *ET* of each elevation band as shown in Figure 6. The maximum ET rate at elevation (818.03-1801m) is in the month of November, which is 106.915 mm/day. At an elevation (818.03-1801m), Maximum ET rate in August month is 5.076 mm/day, Minimum ET in August month is 0.386 mm/day, Median of 2.476 mm/day, Mean value 2.633 mm/day, upper quartile is 3.277 mm/day and lower quartile with 1.942 mm/day.



Figure 6: (a) Daily ET Boxplot statistics (b) Monthly ET Boxplot statistics

Table 2 shows how daily ET varies with elevation change; the lowest elevation band (818.03-1801.5m) and highest elevation band (4750.1 - 5733m) shows that maximum ET increases at the 1.06822E-05 rate, the minimum ET increases by 2.54337E-07 rate

Elevation Dand	Ave ET	MAX ET	MIN ET	Mean ET	
Elevation Danu	AVGEI	rate(mm/day)	rate(mm/day)	rate(mm/day)	
818.03 - 1801.5m	1309.77				
1801.5 - 2784.06m	2292.78	-2.95011E-05	-1.01728E-06	-0.000114952	
1801.5 - 2784.06m	3767.08	2 25428E 05	2 02200E 06	2 45778E 05	
2785.06 - 3767.08m	3276.07	3.23438E-03	2.0339912-00	5.45778E-05	
2785.06 - 3767.08m	5241.55	2 85127E 05	2 02662E 06	0.07042E.05	
3767.08- 4750.1m	3767.08	2.83127E-03	-2.03002E-00	9.9794512-05	
3767.08- 4750.1m	3767.08	2 54248E 05	1.01600E.06	5 80857E 05	
4750.1 - 5733m	5241.55	2.34248E-03	1.01099E-00	5.8985/E-05	
818.03 - 1801.5m	1309.77	1.06822E.05	2 5/337E 07	7 12145E 06	
4750.1 - 5733m	5241.55	1.00822E-03	2.34337E-07	7.12143E-00	

Table 2 ET relation among the elevation band

and mean ET by 7.12145E-06 rate. Similarly table change.

3 shows the monthly ET variation with elevation

Table 3 Change in monthly ET rate with Elevation band

Elevation Dand	Ave ET	MAX ET	MIN ET	Mean ET
Elevation Band	AVGEI	rate(mm/month)	rate(mm/month)	rate(mm/day)
818.03 - 1801.5m	1309.77			
1801.5 - 2784.06m	2292.78	-0.000763493	0.000313796	0.000322194
818.03 - 1801.5m	1309.77	0.000702742	0.00154278	0.001782807
1801.5 - 2784.06m	2292.78	0.000702743	0.00134278	0.001/8380/
1801.5 - 2784.06m	2292.78		0.0001820	0.000240608
3767.08- 4750.1m	3767.08	0.000239443	0:0001829	0.000349008
3767.08- 4750.1m	3767.08		0.000570274	0.000671428
4750.1 - 5733m	5241.55	0.000732467	0.000370374	0.0006/1428
818.03 - 1801.5m	1309.77		0.000502905	0.00069426
4750.1 - 5733m	5241.55	0.000705326	0.000302903	0.00009420

#### CONCLUSION

central role in hydrological, agricultural and drought events. This project estimated the daily ET of each elevation band for the year 2020 within the catchment of Kulong Chuu basin. The daily mean temperature and relative humidity obtained from NCHM and solar radiation from PADS has been interpolated with IDW technique for equally classified elevation band. The ET calculation was based on the Turc method (1961) that uses least parameters under humid conditions. It is based on the some easily available climatic data such as air temperature, solar radiation and relative humidity, and therefore, easy to apply whenever

ET is the only component of water balance with the a full set of climatic data is not available. The Turc method uses Temperature and solar radiation as the determining variables. It was observed that the ET increased at given temperature and radiation with decreasing relative humidity below 50%. At higher relative humidity ET is mainly driven by radiation and temperature and relative humidity does not play a role anymore. At the elevation (4750.01-5733m) observed highest ET of 275.793 mm/month in summer and lowest ET value 184.717 mm/day in winter. With the Annual ET of 395.633 mm/year in Kulong Chuu with Monthly ET ranging from 50-108 mm/month observed highest ET of 109.264 mm/month in the

month of November at the highest elevation and 52.393 mm/month at the lowest elevation. It was observed ET rate at higher elevation (4750.01-5733m) was 2.35% higher compared to the lowest elevation (818.03-1801m). At the elevation (2784-5733m) monthly ET rates of (818.03-2784m) are comparable or even exceed those of lowlands. This implies that in even at the higher elevations considerable ET rates can be observed and that ET rates do not necessarily diminish with higher elevations.

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### DESIGN AND FABRICATION OF CROP HARVESTING MACHINE

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Abstract— Crop harvesting machine is a mechanical machine used for the harvesting of crops such as barley, wheat, buckwheat and paddy. This project is carried out with the objectives to reduce cost, time and labor required to harvest crops efficiently.

This machine is simple and effective in which two mechanisms are used; straight bevel gear mechanism and crank and slotted link mechanism.

Keywords— crop harvesting machine, crank and slotted link mechanism, straight bevel gear mechanism.

#### 1. INTRODUCTION

Agriculture is important in our country; it is the primary source of income for farmers. Most farmers are illiterate and lack access to agricultural facilities. Things must change over time to implement new approaches and equipment that will improve efficiency. Numerous agricultural machines are now available that are very large and could not be used effectively in small farm production. Furthermore, all farmers remove crops by hand, which is a more laborious and time-consuming process. Some farmers experience damage to their hands because of cutting or removing crops by hand, which results in a shortage of labor. To address this issue, a simple but more efficient machine is developed for farmers. This machine is aimed at small-scale farmers with less than 1 to 2 acres of land. This unit can cut wheat, millet, buckwheat, and paddy. So, this machine is mainly fabricated to save time, reduce human efforts and reduce the labor required for cutting the crops.

This machine has the advantage of being lowcost and simple to operate, even though it employs a variety of operations and mechanisms. The differential gear mechanism and crank and slotted link mechanism is used in the design to operate

manually. This crop harvesting machine is made with readily available spare parts, making it simple to maintain. This crop harvesting machine might be the solution to the problems faced by farmers.

#### 2. METHODOLOGY

#### 2.1 Working Principle

The movement of the machine is achieved by the use of wheels. Cutting of crop is achieved by the scissoring motion of cutting blades (1 stationary and 1 movable). Two mechanisms are used in this machine: A straight Bevel Gear mechanism and, a Crank and Slotted mechanism. The Straight Bevel Gear mechanism transmits the power of the drive axle (driver gear) at an angle of 90 degrees to the driven gear (crankpin). The crank and slotted link mechanism convert the rotary motion into reciprocating motion. The driven crank pin's rotary motion is transferred through the rocker arm to the cutting blades to obtain the reciprocating motion.

A bevel gear component (driving gear) is coupled to the drive axles. When the machine moves forward or backward the wheels rotate and drive the driver gear of the bevel gear component which in turn rotates the driven gear. To this driven gear, a sliding block is attached which will slide in the slot provided in the rocker arm. As the driven gear rotates, the sliding block will slide in the slot and rock the rocker arm due to which the rotary motion of the driven gear block is converted to reciprocating (side to side) motion of the movable cutting blades. The rotary motion of the driven gear is transferred to the reciprocating blades through the rocker arm. The rocker arm is pivoted in the middle to achieve side to side reciprocating motion of the movable blade instead of to and fro motion. The cutting speed of the blades is proportional to the speed of the wheels.

#### 2.2 Design

The machine is designed in such a way, to fulfill the objectives of this project. An isometric view of this design is given below (Figure 1). The design of this machine eliminates the use of the fuel-consuming engine or electric motor. It can be manually operated and thereby making it economical. The power source for the machine is from the traction between the wheels and ground, which is transferred to the cutting blade by using the Bevel gear mechanism and Crank and Slotted link mechanism.

The machine is smaller in size and can be used in smaller field sizes. For this, the mainframe or the body frame of the machine is kept compact and is 0.90 m in length and 0.60 m in width. This body frame gives support and houses all the other components of the machine. The machine is moved forward and backward direction by the operator through the waist-high handle supports. The main wheels diameter of the machine is 0.25 m because the height of the blades from the ground has to be as low as possible. This height should be low enough to cut the crop from an appropriate height but high enough to make sure the driving gear does not touch the ground while operating the machine. Another swivel wheel is used to easily change the direction of the machine and is located at the middle of two handle supports. The component that transfers the crank pin's rotary motion to the movable blade to obtain the reciprocating motion is the rocker arm. One end of the rocker arm is attached to the movable blade and the other end of the rocker arm is above the driven gear, the distance between the two ends of the rocker arm is 0.68 m. The slot in the rocker arm is 0.18 m long which is slightly longer than the length of travel of the crankpin which will slide in the slot. For smooth sliding of the crankpin, the slot gap is made slightly bigger than the diameter of the crankpin by 0.015 m. In this machine design, two sets of cutting blades are used, one fixed and one movable. The fixed blade is fixed onto the frame of the machine and the movable blade is placed above it. This movable blade is also linked to the rocker arm and moves relative to the rocker arm as the rocker arm reciprocates. The width of the frame is 0.60 m and, the width of the cutting blades is 0.70 m, made slightly longer than the frame. The blade breadth is 0.18 m. From the blade breadth of 0.18 m, half of the breadth is used to make the teeth of the blades, and the remaining half is used to fix the blade to the frame. The gap between each tooth is 0.05 m so that there is enough space for the stem of the crops to get in between the teeth of the blades.

A straight bevel gear of gear ratio 1:3 is used, which means for every rotation of the driving gear the driven gear rotates three times. The driving gear of the bevel gear system is mounted on the shaft connecting the two wheels of the machine. As the wheel rotates, the driving gear shall also rotate at the same speed. To the driven gear of the bevel gear system, a crankpin is connected and rotates at the same driven gear speed. This is how the rotary motion of the crankpin is obtained. The crankpin will rotate in the slot which is provided in the rocker arm. The gear ratio used in this machine increases the number of blade motions per second. If a higher gear ratio is used the efficiency shall also increase since a greater number of lateral reciprocations will be achieved for each rotation of the wheel. The handle of this machine is fixed onto the body frame and is used to push the machine forward. . The handle of the machine is kept 1m above the ground level so that it is convenient for the average human height to comfortably drive the machine. The design of this machine incorporates all of these components which work about each other to have a machine that serves the purpose of harvesting crops.



Figure 1: Three dimensional view of designed crop harvester

#### 2.3 Characteristics of machine.

1. The assumed operating speed of the machine: 50m/min = 0.833 m/s

2. The number of revolutions made by wheel per minute: 63 rpm.

- 3. Gear ratio: 1:3
- 4. Lateral Reciprocating motion: 378 times/

#### min = 6.3 times/second.

- 5. Area covered: 30 m2/min = 0.5 m2/s
- 6. Machine cost: Nu. 16,500.00
- 7. Machine weight: 21.23 kg

#### 3. RESULT AND CONCLUSION

This project fulfills the objectives of being costefficient, time-saving, labor efficient, and possibly replacing the primitive methods of harvesting crops. To come up with a machine that fulfills all the objectives, a machine is designed employing two mechanisms (crank and slotted link mechanism and bevel gear mechanism) and using materials that are cheap and strong enough for a crop harvesting machine. After designing and then fabricating the machine as planned, the designed machine was practically tested. The two mechanisms that were used proved to be workable and suitable for a crop harvesting machine. The machine is simple and has limited parts making it easy to operate. We can conclude that the project's aims and objectives are successfully achieved.

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#### EFFECTS OF CURING TIME ON COMPRESSIVE STRENGTH OF CONCRETE

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Abstract— The effects of curing time on the strength of M20 concrete grade is investigated in this study. The compressive strength development for non-cured cubes, curing period of 7, 14, 21, and 28 days under room temperature using Portland Pozzolana Cement (PPC) has been investigated. From the experimental observation, it is found that in general, the compressive strength increases with age of concrete irrespective of the curing and its duration. The test results shows that 7 days continuous curing cubes achieved 19.04 N/mm<sup>2</sup> (96%) of the target strength at end of 15 days. It is obvious that it will achieve its target strength at the end of 28 days. The compressive strength of 14 days continuous curing cubes achieved 20.89 N/mm<sup>2</sup> at end of 22 days. The variation in compressive strength of concrete after 21 days of continuous curing doesn't affects much in achieving its target strength. The minimum of 7 days of continuous curing duration is necessary to gain its target strength of Portland Pozzolana Cement (PPC) concrete works. At the early ages as well as at later ages, it is essential have adequate curing for the development of strength for PCC concrete. It is also observed that under the draying ambient conditions, potential development of strength is reduced for PPC concrete.

Keywords—Curing, Non-curing, Compressive Strength, Concrete

#### 1. INTRODUCTION

Curing of concrete plays a major role in developing the micro-structure and pore structure of concrete. Curing of concrete means maintaining moisture inside the body of concrete during the early ages and beyond in order to develop the desired properties in terms of strength and durability. Ponding method of curing was recommended to be the best of all the curing methods as it produced the highest level in compressive strength and cube densities [1]. The effect of Curing delay on concrete in hot weather where they found that properly cured concrete can have significantly superior properties compared to concrete left to set after finishing. Improperly cured concrete can be subjected to plastic shrinkage cracking, loss of moisture from fresh concrete and drying shrinkage which loss of moisture from concrete that has set among other undesired side effects [2].

Impact of curing on strength of concrete demonstrates that the method and duration of curing to a great extent affects the strength of concrete [3]. Different water sources have different levels of impurities and these generally have significant impact on the strength of concrete [4]. The highest compressive strength was achieved in samples that were cured for three days under water, then left to air-dry for 25 days, compared to samples cured using chemical compounds or samples continuously cured under water for 28 days [5].

Concrete gains strength with time after casting as concrete gains its strength rapidly in the initial days after casting. The minimum of 28 days of curing has to be done for the plain concrete under a fine atmosphere in order to gain desire strength [6],[7]. Excessive curing time may lead to the escalation of the construction cost of the project and unnecessary delays [8]. Due to inadequate curing, concrete develops shrinkage cracks, thermal cracks, along with a considerable loss in the strength of the surface layer. The curing of concrete helps in strength development on the surface of the structural member rather than the inner part. The main aim of this paper is to examine the effects of curing time on compressive strength of cement concrete and the variation of strength with respect to time after curing.

#### 2. METHODOLOGY

#### 2.1. Materials and Methods

This study represents a general scenario of

the effect curing on compressive strength of M20 concrete were made with PCC and other locally available materials such as coarse aggregates and fine aggregates. All other parameters were kept constant and curing time was varying from 7 days, 14 days, 21 days and 28 days. The testing of the specimens was done after one day, 4 days, and 8 days after the continuous curing for 7 days, 14 days, 21 days and 28 days respectively.

#### 2.2. Preparation of test specimen

The steel molds (cylindrical in shape with 100 mm diameter and

The specimen was prepared for M20 grade of concrete with the standard mix ratio (1: 1.5: 3). The required water cement ratio is 0.55 and then the water is added until the concrete becomes homogenous and of desired consistency. The steel molds of 150x150x150mm sizes were filled with concrete in layers. Each layer is compacted by tamping not less than 35 strokes with the tamping rod. The tamping rod should enter the previous layer while tamping the subsequent layer. The total of 54 specimens were casted out of which 9 specimens were left uncured. After that, leaving the molded concrete specimens in place of hardening for a period of 24 hrs., and then de-molded.

#### 2.3. Curing of specimens

A curing tank was constructed for curing the concrete specimens properly. The temperature of the curing water varies from 20 to 25° C. The concrete specimens were cured for 7 days, 14 days, 21 days and 28 days respectively. After that, the specimens were kept in air until testing. One set of concrete were left uncured (Air curing).

#### 2.4. Testing of specimens

The effects of curing on compressive strength of concrete with age of concrete is determined in accordance with IS-516 (1959). The compressive strength is one of the most important and useful properties of concrete. It usually gives an overall picture of the quality of concrete because it is directly related to the structure of the hardened cement paste. The compressive strength test of moist cured concrete specimens was conducted after removal of moist storage. The compressive strength of concrete cubes was tested under compressive testing machine

(CTM) after one day, four days and 8 days after the 7 days, 14 days, 21 days and 28 days of curing respectively.



Figure 1: Compressive testing machine (CTM)

#### 3. RESULTS AND DISCUSSION

Compressive of strength of a cured as well as non-cured cubes increases with respect to time but compressive strength of cured cubes is comparatively higher than non-cured cubes. Moreover, strength of cured cubes is achieved as per the desired standard compressive strength of M20 concrete grade. Concrete gain its strength at higher rate in early phase and slow in later phase. Normally concrete can be cure at least for 7 days since it gains its desired strength after concrete if done air curing.

Table 1: Results for full time air curing (Non-Curing)

Full time air curing (non-curing)				
Mode of curing	Curing time (Days)	Load (kN)	Compressive strength (N/mm <sup>2</sup> )	Average compressive strength (N/mm <sup>2</sup> )
	7	110	4.89	6.37
		190	8.44	
		130	5.78	
	- 14	290	12.89	
Full time air curing		220	9.78	
		240	10.67	
		370	16.44	
	28	340	15.11	15.70
		350	15.56	



Figure 2: Compressive strength for air curing (non-curing)

The figure 1 shows the compressive strength of the concrete of M20 grade where the curing is not done. The cubes were kept in the room temperature and compressive strength test was done after 7 days, 14 days, and 28 days. The result shows for 7 days about 30% percent of the targeted compressive strength was gained and 14 days period the strength gain by the concrete was about 55.55 % percent of the targeted strength and for 28 days the strength gain was about 78.5 %.

The result obtained is the compressive strength gain by the concrete after full time water curing for 7 days, 14 days, 21 days and 28 days as shown in table 2. The strength gain at 7 days full time water curing is 10.81 N/mm<sup>2</sup> and 15.41 N/mm<sup>2</sup> after 14 days. The strength gain was rapid in the early two weeks and the rate lowers as in later weeks as 98.15% and 98.5% was achieved which is 19.63 N/mm<sup>2</sup> and 19.7 N/mm<sup>2</sup> for 21 days and 28 days full time water curing.

 
 Table 2: Compressive strength of cured concrete and standard

No. of days of Full time Curing	Compressive Strength (N/mm²)	Standard Strength, (%)	Standard Compressive Strength (N/mm²)
7	10.81	65%	13
14	15.41	90%	18
21	19.63	99%	19.8
28	19.7	99.90%	19.98



Figure 3: Comparison of compressive strength of cured cubes and standard

The figure 3 shows the comparison of compressive strength of concrete obtained after fulltime curing and the standard compressive strength of M20 grade of concrete. In the initial phase, it is observed that there exists comparable difference with almost 10.95% for 7 days full time curing and 12.95% for 14 days curing time. However, in the later phase, after 21 days, the differences observed is minimal as shown in figure 3.

Table 3: Compressive	strength of cured concrete
vs Air curing	(Non-Curing)

No. of days of Full Air Curing (Non-Curing)	Compressive Strength (N/mm <sup>2</sup> )	No. of days of Full time Curing	Compressive Strength (N/mm <sup>2</sup> )	% Difference		
7	6.37	7	10.81	41.07		
14	11.11	14	15.41	27.90		
21	14.5	21	19.63	26.13		
28	15.7	28	19.7	20.30		



Figure 4: Comparison of compressive strength of cured and non-cured cubes

The comparison between the compressive strength of the concrete between full time cured and non-cured cubes is shown in figure 4. It is observed that the compressive strength increases for both the cases as the number of days also increases but the strength gained by the non-curing cubes are comparatively less compare to the cured ones. The result shows the variation of strength is higher at the initial stage of concrete where at 7 days, 14 days, 21 days and 28 days the variations are 41.07 %, 27.9% 26.13% and 20.3% respectively as shown in table 3. It is also observed that the concrete gains strength even if it left uncured, however it doesn't meet the target strength as the IS code standard. At the end of 28 days, the strength gain is only 15.7 N/mm<sup>2</sup> which is 78.5 % of target strength for uncured cubes.

Table 4: Compressive strength of cured concrete vs Air curing vs Sstandard Values

No. of days of Full Air Curing (Non-Curing)	Compressive Strength, N/mm2	No. of days of Full Curing	Compressive Strength, N/mm2	Standard Compressive Strength, N/mm2		
7	6.37	7	10.81	13		
14	11.11	14	15.41	18		
21	14.5	21	19.63	19.8		
28	15.7	28	19.7	19.98		



Figure 4: Comparison of compressive strength of cured vs non-cured vs Standard Values

The figure 4 shows the comparison of compressive strength of non-curing, curing and the standard strength of the concrete of M20 grade of concrete. Comparing the strengths though non-curing cubes also gains its compressive strength but comparatively low as compared to the standard strength. The concrete cubes with full time water cured for 7 days and 14 days also gives lower results at the initial strength, however, at later stages, it is observed that the strength achieves its target strength as that of the standard one as shown in table 4. It clearly reveals that the curing effects the strength of concrete with age of concrete.

Table 5: Full water curing for 7 days

Full time water Curing for 7 days							
Mode of curing	No. of days after curing for Load (kN) Compressive 7 days		Compressive strength (N/mm²)	Average compressive strength (N/mm²)			
		230	10.22	_			
	8 (1 day)	210	9.33	10.81			
		290	12.89	-			
Full time water		320	14.22	_			
curing for 7	11 (4 days)	240	10.67	11.70			
days		230	10.22	-			
		430	19.11				
	15 (8 Days)	460	20.44	19.04			
		205	17.56	-			





Figure 5: Compressive strength of concrete after 7 days of curing

The specimens were cured for 7 days fulltime curing and the test was carried out on 8th day, 11th day and 15th day after the casting of cubes as shown in table 5. This means keeping the specimen one day, four days and 8 days of air curing after 7 days of complete water curing. On the 8th day of concrete age, the strength is 10.81 N/mm<sup>2</sup>. The compressive strength of concrete is 11.7 N/mm<sup>2</sup> and 19.04 N/mm<sup>2</sup> respectively on 11th and 15th days of concrete age. From figure 5, it shows that the strength of the concrete increases at higher rate with age of concrete and achieves 95.2 % of its desired strength for M20 at the end of 15th days after casting.

Table 6: Full water curing for 14 days Full time Water Curing for 14 days

Mode of curing	No. of days after curing for 14 days	Load (kN)	Compressive strength (N/mm²)	Average compressive strength (N/mm²)
	_	375	16.67	
	15 (1 day)	270	12.00	15.41
		395	17.56	
<b>P</b> 11 2		390	17.33	
Full time water	18 (4 days)	350	15.56	16.30
curing for 14 days		360	16.00	
		450	20.00	
	22 (8 Days)	490	21.78	20.89
		470	20.89	



Figure 6: Compressive strength of concrete after 14 days of curing

The specimens were cured for 14 days fulltime curing and the test was carried out on 15th day, 18th day and 22nd day after the casting of cubes as shown in table 6. This means keeping the specimen one day, four days and 8 days of air curing after 14 days of complete water curing. On the 15th day of concrete age, the strength is 15.41 N/mm<sup>2</sup>. The compressive strength of concrete is 16.3 N/mm<sup>2</sup> and 20.89 N/mm<sup>2</sup> respectively on 15th and 22nd days of concrete age. From figure 6, it shows that the strength of the concrete increases at higher rate at initial days with age of concrete and achieves more than 100 % of its desired strength for M20 at the end of 22nd days after casting.

#### Table 7: Full water curing for 21days



Figure 7: Compressive strength of concrete after 21 days of curing

The specimens were cured for 21 days fulltime curing and the test was carried out on 22nd day, 25th day and 29th day after the casting of cubes as shown in table 7. This means keeping the specimen one day, four days and 8 days of air curing after 21 days of complete water curing. On the 22nd day of concrete age, the strength is 19.63 N/mm2. The compressive strength of concrete is 20.81 N/mm2 and 21.85 N/mm2 respectively on 25th and 29th days of concrete age. From figure 7, it shows that the strength of the concrete increases with age of concrete at constant rate and achieves more than 100 % of its desired strength for M20 grade starting from 25th days after casting.



Full time Water Curing for 28 days							
Mode of curing	No. of days after curing for 21 days	Load (kN)	Compressive strength (N/mm²)	Average compressive strength (N/mm²)			
	_	450	20.00	_			
	29 (1 day)	480	21.33	19.70			
		400	17.78	-			
E 11.2	_	500	22.22				
rull time water	32 (4 days)	475	21.11	21.70			
curing for 28 days		490	21.78				
	_	540	24.00				
	36 (8 Days)	550	24.44	23.11			
	_	470	20.89				

The specimens were cured for 28 days fulltime curing and the test was carried out on 29th day, 32nd day and 36th day after the casting of cubes as shown

Compressive strength gain after 28 days of curing



in table 8. This means keeping the specimen one day, four days and 8 days of air curing after 28 days of complete water curing. On the 29th day of concrete age, the strength is 19.7 N/mm2. The compressive strength of concrete is 21.7 N/mm2 and 23.11 N/mm2 respectively on 32nd and 36th days of concrete age. From figure 8, it shows that the strength of the concrete increases with age of concrete at constant rate and achieves 98.5 % of its desired strength for M20 grade. It is also observed that the strength of concrete keeps increasing even after 30 days of age.

Table 9: Variation of compressive strength after curing



Figure 9: Variation of compressive strength after curing

The variation of compressive strength of concrete after different period of curing duration is shown in the table 9. The specimens are tested after one day, four days and 8 days for every 7 days, 14 days, 21 days and 28 days of curing duration respectively. The age of concrete is kept constant while testing the specimens irrespective of curing duration. From the figure 9, it is observed that when the specimens are cured for 7 days, the test result for first day is 10.81 N/mm2. The test results for 4th and 8th days of age of concrete strength is 11.7 N/mm2 and 19.04 N/mm2. For the specimens which was cured for 14 days, the test result for first day in 15.14 N/mm2. The test results are 16.3 N/mm2 and 20.89 N/mm2 for four and eight days respectively. It is observed that the strength variation of first one day and four days for both curing time for 7 and 14 days are minimal as shown in figure 9. The test results for the 8th days shows the variation in strength is high as 62.74% for 7 days curing and 28.16 % for 14 days curing. It is observed that when the specimens are cured for 21 days and 28 days, the variation of strength after curing is very minimal. It ranges from 19.63 N/mm2 to 23.11 N/mm2 for the first 8 days. However, it is observed that the strength increases steadily with time irrespective of curing curation.

4. CONCLUSION

This study was investigated the effect of curing on compressive strength of concrete cubes in terms of different curing duration and with uncured cubes. In general, it is observed that, the compressive strength increases with age of concrete irrespective of the curing and its duration. From this research study, following conclusions are drawn:

• The compressive strength for non-cured cubes achieved only 15.7 N/mm2 (78.5 %) of the target strength at end of 28 days. This reveals the curing is necessary for the concrete to achieve the

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target strength.

• The compressive strength of 7 days continuous curing cubes achieved only 19.04 N/ mm2 (96 %) of the target strength at end of 15 days. It is obvious that it will achieve its target strength at the end of 28 days.

• The compressive strength of 14 days continuous curing cubes achieved 20.89 N/mm2 at end of 22 days, which reveals that the standard target is achieves only after 8 days of air curing.

• The compressive strength of 21 days continuous curing cubes achieved 21.81 N/mm2 at end of 25 days. The air curing of 4 days is required to achieve it standard target.

• The compressive strength of 28 days continuous curing cubes achieved 21.7 N/mm2 at end of 32 days. The air curing of 4 days is required to achieve it standard target.

• The variation in compressive strength of concrete after 21 days of continuous curing doesn't affects much in achieving its target strength according to this research finding.

• The minimum of 7 days of continuous curing duration is necessary to gain its target strength Portland Pozzolana Cement (PPC) concrete works.

• Adequate curing at early ages as well as at later ages is essential in the strength development of PCC concrete. It can be concluded that drying ambient conditions reduce the development of strength of PCC concrete.

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### Monitoring dark web for organization-specific information leakage

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ABSTRACT - The use internet has become a part of every organization's daily activity, and the information of the organization is becoming difficult to be protected from malicious actors even though the security mechanisms are put in place by the organizations. When a data breach occurs, organizations' sensitive information is being made available out on the dark web by cybercriminals. On the other hand, the organization finds it difficult to detect the presence of their data on the dark web. The dark web provides a platform for users who seek to maintain their privacy, but it is also a platform for hosting and carrying out prohibited activities. This paper presents the development of a dark web monitoring tool to detect the presence of leaked information of the organization in the dark web and alert the information security officer of the concerned organization. The tool was developed using Python and successfully experimented with the functionality of crawling, scrapping, and alerting components of the tool. The tool can be customized and used by any organization to monitor the presence of their organization-specific data in the dark web.

#### 1. INTRODUCTION

With the rapid growth and development of the internet and with the online platform, data privacy is also becoming a major concern. And everyone knows the internet is one of the greatest inventions of humans, where many researchers of the various field will add various services to be used by any kind of the users and also maintain security at the same time.

There is a part of the internet known as the dark web, where an individual can do their work away from being attacked and monitored. This part of the internet provides a secure place for many individuals, who are worried about the privacy of their connection via the internet and still want to access the resource on the web while maintaining the privacy of their work. This can be achieved with

the help of technologies that encrypt the connection and such users are mostly universities and education centers, business, and commercial industries.

However, many cybercriminals take advantage of the flip side of the technologies to conduct unethical activities within the dark web, like trading weapons, selling sensitive personal or corporate information, illegal drug businesses, providing access to child pornographic materials, buying and selling of credit card numbers, and etc. Cybercriminals aren't likely to stop anytime soon, so it becomes extremely important to do everything individuals can to safeguard personal information.

This paper explores the concepts for accessing the dark web, layers of the internet, types of activities carried out in the dark web, and the reasons and the technicalities behind the operation of the tor network. Finally, this study experimented with the monitoring of the dark web for detecting the presence of organization-specific information in the dark web.

#### 2. AIMS AND OBJECTIVES

The main aim of this study was to monitor the dark web for organization-specific information leakage with the tool developed using Python, which will crawl the dark web pages and perform the pattern search to detect the presence of organization-specific data and alert the information security personnel of the organization.

#### 3. LITERATURE REVIEW

The Surface Web, Deep web, and the Dark web, Surface web are part of the Internet. The surface web according to [1] [2], refers to the unencrypted part of the internet that the search engine like chrome can index, and the surface web contains the publicly available documents, contents, and information. Visible web, Indexed web or clear web are some of the terms used for surface web. Most individuals view the internet as the glacier at the sea and the only viewable part above the water is the surface web that makes about 4% of the internet.



Figure 1: Parts of the Internet

#### 3.1. The Deep Web

The deep web is the part of the internet that contains the webpages that cannot be indexed, which means the search engines cannot reach the particular webpage but the Deep web is accessible by using any standard browser stated by [2] and the reason mentioned for not able to index a webpage was because the web pages may be protected with a password and also the webpage can be unlined from other web pages which makes it unreachable unless one knows the correct URL.

#### 3.2. The Dark web

Most of the activities per [2] are illegal activities such as drug trading, child abuse, weapons trading, and many more; Guccione [3] also refers to the dark web as the sub-set of the deep web.

The dark web is only accessible with special browsers or software. A few examples of such software or special browser are TOR, the Invisible Internet Project (I2P), or free net. So, Darknet is an infrastructure underneath the Dark web, which is the content and website that can be accessed by only a special browser.

The darkweb sites can be found pretty much like any other site, but Guccione [3] states that there are some important differences such as naming structure. Instead of ending in [.]Com, dark websites will end with [.]onion. Dark web sites also use a jumbled naming structure that forms URLs that are not easily identified and can hardly remember the correct URL.

Dark web monitoring is the method of looking for and keeping updates or track of personal information found over the section of the internet that is not accessible through normal standard browsers. According to Liu et al. [], more than 845,000 stolen credit/debit cards, over 1.2 billion stolen account credentials, and 1.3 million personally identifiable information were being detected while monitoring the activities over the dark web.

To access the dark web requires the use of an anonymous browser called TOR. TOR stands for "The Onion Router". The TOR according to Guccione [3] uses a series of proxy servers operated by thousands of volunteers around the planet, rendering the individual IP address untraceable and unidentifiable.

#### 3.3. Activities of the dark web

According to [4] stated that due to nature its anonymity and privacy, many individuals that act as criminals use the dark web. The law enforcement agencies try to shut down unethical marketplaces and also, they use the dark web to reduce the exposure of government IP addresses and will ensure their anonymity over the dark web.

There is various marketplace within the dark web that deals with the vast number of drugs and illegal substances. And Silk Road is one of the most popular marketplaces and was like eBay over the dark web stated by many sources. The cryptocurrency is not similar to banking online even though the transitions occur online and [5] stated that cryptocurrency is the main standard method used for the operation of the dark web.

#### 3.4. Web Crawling and scraping

Web crawling refers to the process that makes use of bots or an automated script to go through the contents on websites for archiving and indexing purposes. These automated scripts or bots are very well known by many multiple names, spider, crawler, and often spider bot. Crawlers have a lot of uses in various applications and research areas, aim to get updated data.

Web scraping according to [6], is the process that is mainly used to collect and parse raw data from the Web Pages, but some websites prohibit individuals from scrapping the data with automated tools like the ones we have created for this project because according to [6] the sites has a legit explanation to protect their data and also by making many repetitive requests to the website's server may utilize the bandwidths that will lead to slow down the website for other legit user and will potentially overload the server and will take the websites down completely.

#### 4. METHODOLOGY

#### 4.1 Hidden Services URLs

The first obstacle in scraping the dark web is looking for and collecting the hidden services links called seed URLs to scrap. Some of the places which provide hidden URLs are Hidden Wiki Directories and the Hunchly Service. The URLs provided by the Hidden Wiki and the Hunchly service were saved to a file so that the Crawler can use them as the seed URLs.

#### 4.2 To Build Crawler

A web crawler was developed that will fetch all the URLs and will go to the next URL and also fetch until all the URLs are collected and will be stored in a file. The crawler is designed such that it will not collect the same URL more than once.

#### 4.3 Monitoring Process

The process of crawling the dark web, scraping, and alerting the user is shown in Figure 2. Firstly, the crawler makes anonymous connections to the TOR websites, then crawls the sites looking for the patterns to detect the presence of the organizationspecific information. If specific information such as the email address is found in those TOR sites, the user will be alerted to make the timely intervention if in case the specific information has been leaked.

#### 4.4 Alert System for the User

This system is designed to send the emails to the particular individual if any information is found after monitoring the dark web and with this system, it will be easy to alert the particular individual too with the message containing the URL from where scraper got the specific data and will let the individual take necessary action.



Figure 2: The monitoring process

#### 5. RESULT

The developed tool was able to connect anonymously to the TOR site, crawl, and look for patterns specified in the code to find out whether the information of a specific pattern is present or not. If the information matching the pattern is found present, then the tool sends the alert to the specified email of the user. The following figure shows the tool successfully making the anonymous connection to the TOR site masking the actual IP address of the system.

ORIGINAL IP address = 103.197.177.89 ORIGINAL COUNTRY Bhutan	
THE TOR IP address = 185.56.80.65	
CONNECTION INITIATED !!!	

Figure 3:Making an anonymous connection

Figure 4 is the collection of [.]onion URLs saved to a file after visiting the seed URLs which can be used for scraping and pattern matching in the next.

http://p531f57govyuvwsc6xnrppyply3vtgm716pcobkmygsiofyeznfu5ugd.onion/article/ho
http://p531f57govyuvwsc6xnrppyply3vtgm716pcobkmygsiofyeznfu5ugd.onion/article/he
http://p531f57govyuvwsc6xnrppyply3vtgm716pcobkmygsiofyeznfu5ugd.onion/article/wh
http://p531f57govyuvwsc6xnrppyply3vtgm716pcobkmygsiofyeznfu5ugd.onion/article/wh
http://p531f57govyuvwsc6xnrppyply3vtgm716pcobkmygsiofyeznfu5ugd.onion/article/yo
http://p531f57govyuvwsc6xnrppyply3vtgm716pcobkmygsiofyeznfu5ugd.onion/series/gut
http://p531f57govyuvwsc6xnrppyply3vtgm716pcobkmygsiofyeznfu5ugd.onion/article/tr
http://p531f57govyuvwsc6xnrppyply3vtgm716pcobkmygsiofyeznfu5ugd.onion/article/ho
http://p531f57govvuvwsc6xnrppvply3vtgm716pcobkmvgsiofyeznfu5ugd.onion/article/se
http://p531f57govyuvwsc6xnrppyply3vtgm716pcobkmygsiofyeznfu5ugd.onion/article/th
http://p531f57govyuvwsc6xnrppyply3vtgm716pcobkmygsiofyeznfu5ugd.onion/article/tu
http://p531f57govyuvwsc6xnrppyply3vtgm716pcobkmygsiofyeznfu5ugd.onion/article/in
http://p531f57govyuvwsc6xnrppyply3vtgm716pcobkmygsiofyeznfu5ugd.onion/article/he
https://www.facebookcorewwwi.onion/sharer/sharer.php?u=http://p531f57govyuvwsc6x
https://twitter.com/intent/tweet?url=http://p531f57govvuvwsc6xnrppyply3vtgm716pc
http://p531f57govyuvwsc6xnrppyply3vtgm716pcobkmygsiofyeznfu5ugd.onion/atpropubli
http://p531f57govyuvwsc6xnrppyply3vtgm716pcobkmygsiofyeznfu5ugd.onion/atpropubli
http://p531f57govyuvwsc6xnrppyply3vtgm716pcobkmygsiofyeznfu5ugd.onion/atpropubli

Figure 4:URLs collected by the crawler

The following figure shows a redacted URL link sent as a part of the alert to the user's email id whenever the particular pattern has been matched.

el3@9 to bcc: jnec0518024	gmail.com	
hi <b>utan</b> utan your information wa	as being found over d	lark web
the source link is	https://	
Reply	Forward	

Figure 5: Alert sent to the user

#### 6. CONCLUSION

This paper experimented the monitoring and detecting the presence of organization-specific sensitive information in the dark web using the tool developed with Python. The experimental result showed that the tool was able to make the anonymous connection to the TOR sites, crawl, scrap, and perform the pattern matching. After finding the information matching the specified pattern, the tool can send the alert to the user successfully, thereby giving time to prevent further damage caused by the data breach or the information leak. This tool can be customized by any organization to suit their needs; change the patterns to focus on different keywords or patterns to suit the time, nature, and organization.

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## IMPACT OF COVID-19 ON CONSTRUCTION PROJECT: A CASE STUDY ON THE CONSTRUCTION OF MECHANICAL ENGINEERING BLOCK AT JNEC

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Abstract – This paper presents the case study on the construction project of mechanical engineering block at Jigme Namgyel Engineering College.Due to the current pandemic, it is observed that a large number of construction projects were affected in many ways. This paper has attempted to study the impact of COVID-19 on the construction project specifically on material and labor supply. While undertaking the study the data were collected using mixed method that is qualitative and quantitative research approaches. The study considered two broad areas of material and labor supply and also includes other smaller areas. The study could determine total of 20 factors related to materials and labor supply out of which only 10 factors having a high relative importance index are selected as the major factor affected by the COVID-19 on the identified construction sector.

### Keywords: Construction Project, COVID-19, Material Supply, Labor

#### 1. INTRODUCTION

The construction industry is the vital component for economic sector that plays a crucial role in the social and economic development of the country. Creation of job opportunities, expansion of investment options, and improvement in the country's national revenue are the prime contribution of the construction industries to the national economy. However, on 11th March 2020, the World Health Organization (WHO) proclaimed the Coronavirus (COVID-19) as a pandemic [1], indicating the disease's global expansion and is facing regulatory challenges and risks in all industries, including the construction industry due to the spread of COVID-19.

Since 14th March 2020, the impact of pandemic is severely felt in Bhutan as many construction projects has also affected. The coronavirus has created a fall in the productivity or output of the construction

sector causing the further shrinking of the overall economic activity of Bhutan.

Considering the impact of COVID-19 in the construction sector the study has choose the construction of mechanical Engineering block at JNEC as case study. The construction project of Mechanical Engineering Block awarded to M/s Pema Junay Construction Private Limited with the allocated budget of Nu 60.979 million funded by the Government of India. The project commenced on 21st April 2020 amid COVID-19 and it is suppose to be completed on 22nd April 2022 over the span of 22 months. Thus, the construction of mechanical block has to comply with the government regulations and travel restrictions as well as manage the supply chain interruption and delay in execution due to outbreak of COVID-19. This study concentrates on the effect of the COVID-19 on the construction workforce, material supply, and overall impact of COVID-19 on construction activity.

The study aspects to identify some of the major impact of COVID-19 on material and labor supply of the identified construction project. In addition, the study also aspects to look into other areas and provide recommendation that might be benifical for the identified construction project.

#### 2. LITERATURE REVIEW

The COVID 19 has impacted the construction industry in a variety of ways, including loss of labor, lack of supplies, increased cost of construction material, and the change in demand [2]. It is hard to complete most of the construction projects in time as per the set contracts.

Likewise, the COVID-19 pandemic has also negatively impacted the supply chain of materials of the construction project [3]. The efficient management of materials is critical to the successful completion of a project. Material control is an extremely important and vital subject for any company, and it must be handled effectively for a project to be completed successfully. A well-managed materials management system can contribute to the cost-effectiveness of a project [4] . An effective material management system can bring many benefits for a company. Previous studies carried by the Construction Industry Institute (CII) concluded that Labor productivity could be improved by six percent and can produce 4-6% additional savings [5]. However, the current pandemic has caused many negative impacts on materials such as; delays in supply of materials, unavailability of materials, not getting the right quality and quantity of materials for the project.

#### 3. METHODOLOGY

This study has used mix method, qualitative and quantitative approaches for collecting data. A total of 25 respondent were involved in construction project were provided survey questionnairs. For the purpose of qualitative data, structured interview was conducted with 8 selected members from the construction project



Figure 1: Flow Chart

#### 3.1.Pilot Study

The pilot study is carried out before the research design is finalized to assist in defining the research question or to test the validity of the proposed study design. The pilot study was conducted by distributing the initial questionnaire to a selected expert having experience in the same field of the research to have their comments and feedback.. The

first part Section A, which consisted of five (5) YES or NO type questions was designed and was asked to verify the validity of the questionnaire topics and their relevance to the research objective.

#### 3.2. Approach

The qualitative and quantative approach were used to collect data. The quantative data was achieved through the survey questionnaires which was provided to the 25 respondents. qualitative data was collected through structured interview conducted with the 8 selected respondents of the identified construction project.

#### 3.3. Data Analysis

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The tools used for the data analysis are RII, Atlas and Microsoft Excel. The data collected from the questionnaire Survey was analyzed using RII Statistical tool to find the major factors impacting labor and material supply in the identified construction project. Thematic analysis was done using ATLAS.ti 9 to analyze data collected from interviews. The data collected from the interview were used to obtain the views of the respondent on the effects of COVID-19 on the construction project. The following formula is used to determine the relative important index:

$$RII = \sum \frac{\nu \nu}{A * N}$$

Where W is the weighting assigned by each respondent on a scale of one to five. A is the highest value and N is the total number of respondents.

#### 4. RESULT AND DISCUSSION

The graph in figure 2 determines the five major factors impacting the materials supply due to COVID-19. The ranking of the factor is determined according to the RII. Thus, the factors with high RII value are grouped as major factors which affect the construction sector in terms of materials supply. The relative importance index for "Difficult in import of materials due to border seal" is very high (0.91). The relative importance index for "In-efficiency of virtual/online communication with the supplier" is also very high (0.86) with a rank equal to (2). The respondent strongly accepted this as one of the factors affecting materials due to the COVID-19. The approach of procurement has been changed due to COVID-19 with relative Important Index (0.85) is given importance by the responded as the holding of materials in dry port has also affected the construction project mainly at JNEC. The relative importance for the factor "Delayed material supply due to holding in mini dry port" has also indicated a high RII value (0.84) which is ranked 4. High transportation cost which has RII equal to (0.82) is also seen as an important factor.



Delayed material supply due to holding in mini dry port.

High transportation cost

#### Figure 2: Major factor affecting materials supply due to COVID-19

Major Factors affecting labor 1.00 0.98 0.98 0.96 0.96 0.93 0.94 0.92 0.92 0.89 R 0.90 0.88 0.86 0.84 Factors The Mandatory quarantine for workers brought from other dzongkhags cause delay Complex procedure for import of foreign labors Lack of skilled labor in locality. Difficult to work at the site following the COVID

 Difficult to work at the site following the COVIL protocol

Bhutanese laborer demand for high wage rate.

## Figure 3: Major Factors Affecting Labor due to COVID-19

From Figure 3 displayed, the factor with RII (0.98) "Mandatory quarantine for workers brought from other dzongkhags cause a delay in reaching the Labor to the site" has a high rank (1) of all other factors. Similarly, with high RII (0.96) "Complex procedure for obtaining the Labor permit" has obtained a rank equal to (2). "Lack of skilled Labor in the locality" has also very high RII (0.93) due to the government restriction on the import of foreign Labors. It is depicted that with RII (0.92) having

a rank equal to (4) "Difficult to work at the site following the COVID protocol" emerged as one of the major factors affecting the output of the Labor at the construction site. The majority of the respondent marked "Bhutanese Laborer demand for high wage rate" as a significant factor with RII value (0.89).

## 4.1. Comparison of Financial plan with Actual Progress

According to their original work plan Nu. 25.5 million should have been spent on the project and 40 percent of the work should have completed. As of now Nu 3.8 million has been claimed by the contractor excluding the mobilization and material advances. As per their financial plan Nu 1.9 million should have been spent to complete 12 percent of their work. However, Nu 3.8 million has been spent to complete 12 percent of their work. Due to the impact of COVID-19 on transportation, materials cost and Labor, there has been an increase in the total expenditure of the construction by Nu 1.9 million.

4.2. Comparison of Physical Progress with schedule





Figure 4 shows the delay in execution of the work as per the schedule plan due to COVID-19. As per the scheduled plan, 40 percent of the work should have been completed as of April 2021 but due to the impact of COVID-19, only 12 percent of the work has been completed. As per the projected plan bricks work should have been completed but due to the lockdown, the project was suspended for a period of 21days from August 11 to September 1.

However, the delay in execution of the work as per the scheduled plan to complete the project on the period of 22 months, affects the college in shortage of classes for Mechanical Engineering students the upcoming semester and other related services to the students of Jigme Namgyel Engineering College.

#### 5. SUMMARY OF THE FINDINGS

From the research it was found out that difficult in import of material due to border seal, in-efficiency of virtual/online communication with the supplier, the approach of procurement has been changed due to covid-19, delayed material supply due to holding in mini dry port, High transportation cost are the major factor affecting the materials supply due to COVID-19. In the same way, the mandatory quarantine for workers brought from other dzongkhags causes delay in reaching the labor to the site, complex procedure for import of foreign worker, lack of skilled labor in the locality, difficult to work at the site following the covid protocol, Bhutanese laborer demand for high wage rate.

From the comparative analysis of the physical progress with the initial plan, it was found out that the project is delayed by 28 percent in the execution of the work as per the initial plan which would result in a delay in completion of the project. The financial implication due to the outbreak of the pandemic as of now is Nu. 3.8 million of the budgets that have been used for completion of 12 percent of the total work, which is double the cost of their original financial plan. Therefore, the construction project will have a cost overrun to complete the work.

The COVID-19 has impacted the overall construction activity of the project, with the disruption in the supply of materials and inadequate labor to execute the construction activity. The project is likely to delay about 10 months. The delay due to pandemic could affect both the client and the contractor, it can lead to dissatisfaction for the client and the contractor shall incur a loss on completion of the project. With the delay in the construction project, the college is likely to face a shortage of classrooms

for the upcoming semester and fail to provide other services to the students of JNEC.

#### Conclusion

The COVID-19 pandemic has resulted in substantial disruptions in the supply chain of material and labor in the construction project. The global COVID-19 pandemic has a significant impact on the construction industry, resulting in shrinkage of the economy. COVID-19 has had an impact on Bhutan's construction projects, and the construction industry has slowed as a result of the lockdown. This research looked closely at how the pandemic has impacted the construction project and analyzed the current situation where construction projects face problems. The study findings identified that the construction project experienced several adverse effects of COVID-19. These included Impact on Materials Supply, Labor and caused delay in completion of project.

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#### Improvement of transient stability using fuzzy logic power system stabilizer

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Abstract—As power systems become more interconnected and complicated, analysis of complex performance of power systems becomes more important. Synchronous generators are critical to the reliability of power grids. Electric power stability is becoming more important as the popularity of electric goods grows. The power system stabilizer can be used as a means to bring the stability in the power system however it is not without its drawback and limitation. The fuzzy logic controller technique can be used to put power system reliability to a higher level. In this paper the membership function of the rule based fuzzy inference system is increased to supposedly achieve better performance as compared to the already existing rules. In this paper the membership function is increased to 13 and it was found to show better performance compared to the already existing rules. Another combined approach of neural network and fuzzy logic also known as the ANFIS (Adaptive Neuro Fuzzy Inference System) is used to further improve the stability of the power system. The ANFIS shows further improvement in the result which creates the IF-THEN rules based on learning.

### Keywords— PSS, ANFIS, Synchronous generator, Fuzzy Logic, Fuzzy Logic Controller.

#### 1. INTRODUCTION

The power systems are often most of the time subjected to disturbances [1]. The disturbances occur due to loss of transmission line or due to faults occurring on the transmission lines. These disturbances cause electromechanical oscillation or power swings in the power system network. Synchronous generators are critical to the stability of power grids. Electric power stability is becoming more important as the popularity of electric goods grows. As a result, an automatic voltage restorer (AVR) is needed when using delicately constructed electric equipment or in places where the power

supply is not always stable.

Power system stabilizers are widely used in the operation of large electric power systems. The traditional PSS, which employs lead-lag compensation and gain settings tailored to particular operating environments, performs poorly under a variety of loading conditions [3]. As a result, designing a stabilizer that can operate well in all operating modes of electric power systems is extremely challenging. In order to cover a broad range of operating conditions, a fuzzy logic controller has been proposed as a potential solution to solve this challenge, using linguist knowledge and preventing the use of a complex mathematical model while providing good results under a variety of operating conditions. The importance of ensuring the power system's reliability is growing as the system grows in size and continues to evolve. For this purpose, the use of power system stabilizer is becoming more popular in maintaining the power system stability [4]. However, the design of power system stabilizer is cumbersome as there is a need of exact mathematical model of power system. To overcome such problem fuzzy logic controllers are used thereby eliminating the requirement of exact mathematical model of the power system as well as providing better stability [5].

#### 2. POWER SYSTEM STABILIZER

Basically, a PSS introduces a signal in the excitation system which will create a damping torque that is in synchronism with the rotor swing so as to provide the necessary damping to the oscillations of a generator-rotor. The rotor oscillations are basically caused by the minor signal disturbances which in turn are produced due to the small changes in the reference voltage of the AVR [3]. The PSS can be very effective in damping the rotor swings if it is designed in such a way that it has an extensive range of operating conditions. However, if a severe disturbance or fault is subjected to the system, the power system stabilizer won't be able to ensure all the time stability of the power system [4].



Figure1: Power System Stabilizer Structure

Source: adapted from [9]

#### 2.1. Stabilizing Signals For PSS

Many factors affect the selection of a PSS's stabilizing signal. The signals should be readily available in the region, easy to quantify or synthesize, and have a high signal-to-noise ratio. In the current date, numerous PSS designs have been recommended using various input parameters such as speed, electrical power, rotor frequency. The rotor speed signal is frequently used.

Speed: A PSS with rotor speed as its input must produce a torque that is synchronized with the speed change in order to improve damping of rotor swings [7].

Power as input: Because of its low-level torsional interaction, the use of accelerated power as an input signal to the power system stabilizer has gotten a lot of attention. The benefit of an accelerating power signal is that it is resistant to very low-level torsional interactions.

Frequency as input: If the external transmission system grows weaker, the sensitivity of the frequency signal to the rotor input increases when compared to the speed as an input, which tends to balance the decrease in gain from stabilizer output to electrical torque, as seen by the input signal sensitivity factor concept [6, 7].

#### 3. FUZZY LOGIC

#### 3.1 Fuzzy Logic

"Fuzzy logic is a generalization of standard logic, in which a term can have a degree of truth somewhere between 0.0 and 1.0," writes Charles Elkan. Only absolutely true (degree of truth 1.0) or completely false (degree of truth 0.0) principles are covered by standard logic [8].

Many, big, much larger than, young, and other concepts with no clearly defined boundaries pervade our understanding of reality – for example, many,

tall, much larger than, young, and other concepts are valid to some degree but also false to some extent. Since they are interpreted by the human brain rather than computers, these concepts (facts) maybe referred to as fuzzy or (gray or vague concepts) (they make decisions based on strings of 0s and 1s). Programming languages are not fuzzy, whereas natural languages are. Natural languages are much more advanced than programming languages in terms of complexity.



Figure 2: A fuzzy logic system that accepts ambiguous data and statements such as low, medium, and high and makes decisions based on them.

Source: Adapted from [8]

#### 3.2 Classical Sets

Absolute or crisp constraints define the classical collection in which we will be working. This implies that the position of the limits for these sets is absolutely certain. The boundaries of a fuzzy set are undefined since its properties are ambiguous and uncertain. Crisp sets are those in which it is obvious who is a member of the group. When grappling with vague concepts, fuzzy set theory is a valuable tool. The fuzzy sets are explored after looking at the concepts of classical and crisp sets [8].

#### 3.3 Fuzzy Sets

A fuzzy set is one that contains elements of varying degrees of membership in the set. A member of a crisp set cannot be a member unless their membership id was delegated a value of 1. Element in a fuzzy set can be part of other fuzzy set within a same universe as their membership need not necessarily have to be complete. The fuzzy set is mapped to a real-number value between 0 and 1. If an element of the universe, say x, belongs to the fuzzy set A, the mapping is  $\mu A(x) \in [0,1]$ . This is the membership mapping, which is shown in the diagram below [8].



Source: Adapted from [8].

#### 3.4. Membership Function

The fuzziness of a fuzzy set is determined by its membership functions. Whether the element in a set is discrete or continuous is determined by its fuzziness. There are numerous ways to build a membership function one such way could be the use of graphical representation. Similarly, there are various shapes that can be implemented in the graphical representation. However, there are few restrictions and limitation in the usage of the shape. As the name suggests (fuzzy logic) the implementation or the application of the rules concerning the fuzziness under application are most of the time unclear. The membership function maybe created in variety of methodology depending upon the convenience.

The membership function's feature is defined by three properties [5]. They are:

- a. Core
- b. Support
- c. Boundary

#### a. Core

If suppose the region of the universe (x in our earlier example) is embodied by a value of 1 (also known as the complete membership function), then this represents the core of the membership function.

#### b. Support

If the area of the universe is marked by nonzero membership in set A, the support of a membership function for fuzzy set A is specified. The help is made up of elements with a membership greater than zero.

#### c. Boundary

The membership function boundary for fuzzy set A is defined by an area of the universe that has a nonzero membership but is not a complete membership. The boundary is made up of elements whose membership is between 0 and 1.



Source: Adapted from [8]

#### 3.5 Fuzzification

In any fuzzy logic theory, the concept of fuzzification becomes important and crucial part of it. In a simple term the fuzzification is a method of converting a crisp set into a fuzzy value (gray value). To obtain the required fuzzy set the one need to identify uncertainties present in a given crisp set and define it accordingly. Membership function represents the conversion of fuzzy values.

Measurement of voltage, current, temperature, etc., in utility company or industry may involve certain negligible errors which causes inaccuracy and reduction in the precision of such measurement. Such can be represented by the membership function and fuzzification can be performed. In a way fuzzification assigns different membership values to the crisp quantities [4].

#### 3.6 Defuzzification

After the fuzzification process whereby a crisp set is converted to gray value, it needs to be reconverted to crisp value, this is known as defuzzification process. Hence a defuzzification maybe defined as the conversion of fuzzy to crisp value. The main reason for the defuzzification process is due the fact that the fuzzy result cannot be used as it is in the applications, the fuzzy value should be mandatorily reconverted back to crisp value for the processing to be possible. This can be achieved through the process known as the defuzzification process. Through the process of defuzzification one will be able to convert the fuzzy value into a crisp single-valued quantity or a series, or convert it to a form in which the fuzzy values actually exist. The defuzzification maybe also known as the "rounding off" method or technique.

#### 3.7 Fuzzy Inference System

Fuzzy rule-based systems, fuzzy models, fuzzy expert systems, and fuzzy associative memory are

all terms used to describe fuzzy inference systems (FISs). A major component of a fuzzy logic scheme is the fuzzy logic assembly. The process of decisionmaking is critical to the overall system's success. The FIS develops appropriate guidelines, which are then used to make a decision. This is mostly focused on fuzzy set theory, fuzzy IF-THEN laws, and fuzzy logic principles. To create the requisite judgment rules, FIS employs "IF ... THEN ... " statements with "OR" or "AND" connectors in the rule declaration. The simple FIS will take either fuzzy or crisp inputs, but it almost always generates fuzzy sets as outputs. It is important to provide a crisp output while the FIS is used as a controller. As a result, the defuzzification procedure is used in this case to derive the best crisp value that best represents a fuzzy package [8].



Figure 5: Fuzzy Inference System

Source: Adapted from [8]

Each block of the fuzzy inference system has its own function they are as follows:

- the rule base contains a number of IF-THEN rules;

- a database, it defines the membership function for the fuzzy rules;

- a decision-making actually performs the inference operations;

- a fuzzification interface converts the crisp set to fuzzy set; and

- a defuzzification reconverts the fuzzy value to crisp set foe further processing.

4. ADAPTED-NEURO FUZZY INFERENCE SYSTEM (ANFIS)

ANFIS stands for Adaptive Neuro-Fuzzy Inference System, ANFIS is also known as adaptive network based fuzzy inference system. This is a type of artificial neural network which is also based on Takagi-Sugeno fuzzy inference system. This methodology was invented somewhere in the early 1990s. There are several advantages associated with the use of ANFIS, however the main advantage is that this system combines the advantage of both the neural network and fuzzy logic concept in a single concept as it uses both the type of AI based technique. The inference method is made of series of fuzzy IF-THEN rules, the advantage of this rule is that it gives the ability to estimate non-linear function by learning. In a way the ANFIS can be regarded as the universal estimator. The effectiveness of the ANFIS maybe increased by utilizing genetic algorithm by obtaining the best parameters. It's used in intelligent energy control systems that are mindful of their surroundings [8]. The ANFIS model has the benefit of combining numerical and linguistic expertise. The power of the ANN to interpret data and recognize patterns is also used by ANFIS. Even though one can use the ANN for any application the advantage of using ANFIS is that the ANFIS model is more open to the consumer than the ANN and produces less memorization errors.

ANFIS basically comprises of five layers in total (layer 1, layer 2, layer3, layer 4 and layer 5).



Figure 6: Layers involved in the ANFIS

Source: Adapted from [8]

#### 5. MODELLING

The hydropower power plant with its components and the fuzzy power system stabilizer is shown in the figure below. For the purpose of comparison default values of the model were taken and the result was observed. This is shown in the following picture.

## 6. DESIGN OF FUZZY LOGIC RULE TABLE 6.1 13 membership function

Particularly in our case, the fuzzy logic rule table can be constructed with the help of an operator's experience and his knowledge. However, the problem that one can clearly observed is the same control action for the same input. One possible way



Figure 7: The synchronous generator with excitation system and fuzzy logic controller

to overcome such problem could be by increasing the number of control action. Thus, a new fuzzy logic controller based on a rule table with not only increased number of membership function but also with increased number of control action was developed.

The fuzzy logic controller with 13 membership function can be constructed with the following approach [10].

The diagonal element of the rule table is the zero or the neutral control action, the off-diagonal element shows the negative and positive control action [10].

N1, N2, N3, N4 M5, N6, N7, N8, N9, N10, N11 and N12 represent the magnitude of negative control action.

P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, P11 and P12 represents the magnitude of positive control action.

Table 1. Rule table for 13 membership function

dw P	NVV	NV	NL	NB	NM	ZS	ZR	PS	PM	РВ	PL	PV	PVV
NVV	N12	N11	N10	N9	N8	N7	N6	N5	N4	N3	N2	N1	ZR
NV	N11	N10	N9	N8	N7	N6	N5	N4	N3	N2	N1	ZR	P1
NL	N10	N9	N8	N7	N6	N5	N4	N3	N2	N1	ZR	P1	P2
NB	N9	N8	N7	N6	N5	N4	N3	N2	N1	ZR	P1	P2	P3
NM	N8	N7	N6	N5	N4	N3	N2	N1	ZR	P1	P2	P3	P4
NS	N7	N6	N5	N4	N3	N2	N1	ZR	P1	P2	P3	P4	P5
ZR	N6	N5	N4	N3	N2	N1	ZR	P1	P2	P3	P4	P5	P6
PS	N5	N4	N3	N2	N1	ZR	P1	P2	P3	P4	P5	P6	P7
PM	N4	N3	N2	N1	ZR	P1	P2	P3	P4	P5	P6	P7	P8
PB	N3	N2	N1	ZR	P1	P2	P3	P4	P5	P6	P7	P8	P9
PL	N2	N1	ZR	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
PV	N1	ZR	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
PVV	ZR	P1	P2	P3	P4	P5	P6	Ρ7	P8	P9	P10	P11	P12

7. DEVELOPMENT OF FUZZY LOGIC CONTROLLER

The fuzzy logic controller was designed with respect to the rule table developed in the earlier case. The output membership grade of each membership function needs to be correctly calculated logically, for a problem such as the one solved in this paper involving the use of Mamdani fuzzy inference system. With further increase in the number of memberships function the fuzzy set tends to become distorted as shown below. This shows that though the number of membership function can increase, after certain number the fuzzy set becomes distorted which must be strictly avoided.



Figure 8: Fuzzy Logic designer showing the input and the output

## 8. RESULTS AND DISCUSSION 8.1 Applying 3-Phase to Ground Fault

The model was simulated with the disturbance being produced by the three-phase fault block in the transmission line. First the transient response of the generator was plotted without the fuzzy power system stabilizer (FPSS). Next the fuzzy power system stabilizer was used to study the improvement in the transient response of the generator.



Figure 10: Fuzzy set for the 15-membership function showing the distorted peaks

Each simulation was carried out with different number of membership function. In each of the following case three phase to ground fault was applied to the transmission line.



Figure 11: Transient response without FPSS.



Figure 12: Transient response with FPSS (5 membership function)

The data for ANFIS was fed into the Neuro-fuzzy designer and trained to generate a FIS for the fuzzy



Figure 13: Transient response with FPSS (9 membership function)







Figure 15: Transient response with FPSS (13 membership function)

8.2 Applying Single Phase to Ground Fault



Figure 16: Transient response without FPSS



Figure 17: Transient response with FPSS (5 membership function)



Figure 18: Transient response with FPSS (9 membership function)



Figure 19: Transient response with FPSS (11 membership function)



Figure 20: Transient response with FPSS (13 membership function)

logic controller. The data for training the ANFIS was roughly taken from the fuzzy logic controller designed for the earlier experiment.

The data was then used to train the ANFIS to generate the required FIS for the fuzzy logic controller.

The data was fed to the Neuro-fuzzy designer and was tested to confirm the alignment of the trained ANFIS with the input data.



Figure 21: Training data loaded into the Neuro Fuzzy designer.



## Figure 22: Training of ANFIS and structure of the ANFIS model

After loading, training and testing the ANFIS data, the generated FIS was loaded into the fuzzy logic controller to study its effect on the stability of the system.



Figure 23: Testing of the ANFIS data, comparison between trained and test data



#### CONCLUSION

Power is extremely non-linear in nature which means various disturbances occurs in the system and it can bring instability in the power system. Thus, the need to maintain the stability increases. PSS can be seen as an effective means of bringing the stability in the power system however the need for tuning in such case becomes cumbersome. Therefore, without exact mathematical model of the power system as well without the requirement of tuning of the power system stabilizer, fuzzy logic controller can be implemented. The fuzzy logic controller is able to bring the power system back to stable condition following a fault. Higher the number of membership function better was the stability. However, the membership function could not be increased indefinitely as the fuzzy set tends to get distorted which consequently results in the loss of control signal. The performance of the

fuzzy logic was found to be better when ANFIS was used to write the rules for the fuzzy logic controller. ANFIS tends to have better results as it writes the rules based on learning.

#### FUTURE SCOPE

Other AI techniques such as GA can be implemented with the fuzzy inference system to obtain the similar results and perform comparative analysis.

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### WATER TREATMENT USING HIGH VOLTAGE PULSATION

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Abstract – The provision of safe drinking water is regarded as a significant public health achievement for our time. Water-borne illnesses continue to be the third leading cause of mortality. Existing disinfection systems rely on the use of chemicals to protect water production, which poses a slew of questions beyond disinfection effectiveness. High voltage pulse generators can be used successfully in water treatment systems for bacterial decontamination. When a pulsed electric field is applied to a contaminated water sample, all unhealthy germs and bacteria are killed. A modular high voltage pulse-generator with sequential charging is proposed in this paper for water treatment using underwater pulsed streamer corona discharge. The proposed generator is made up of series-connected modules that resemble the arms of a modular multilevel converter. The capacitors in the modules are sequentially charged from a comparatively low voltage DC supply, then attached in series and discharged into the load. This paper proposes configurations for low repeated pulse rate applications in which the equal resistance of the contaminated water sample is used as a charging resistance for the generator's capacitors during the charging phase. In this paper, detailed designs for the proposed pulse generators are simulated. For the experimental setup, precise item specifications are given.

Key words - Pulse generator; voltage multiplier; water treatment

#### 1. INTRODUCTION

Pulsed electric field disinfection is one of the most effective methods for bacterial decontamination since the produced pulsed electric field is capable of killing harmful microorganisms by irreversible permeabilisation of cell membranes [1]. Classical high voltage pulse generators are classified into

different types such as the single capacitor charge/ discharge circuit, magnetic pulse compressor, pulse shaping network, multi-stage Blumlein lines, and Marx generator [2]. For pulsed power applications, the Marx generator is the most common and dependable classical topology. The Marx generator's basic principle is to charge all capacitors in parallel (i.e., store energy), then bind them in series during discharging via closing switches. A modular high voltage pulse generator for pulsed power applications is proposed in this paper. Similar to DC-AC and DC-DC serial multilevel converters, the proposed generator is made up of series-connected units (MMC).

The capacitors in the modules are charged sequentially from a comparatively low voltage DC supply, then attached in series to be discharged in the load. A cascaded multilevel DC-AC converter is presented in[5]. This topology is built on the use of cascaded half-bridge sub-modules (each submodule is fed from an independent dc source) to produce a repeated up-down staircase waveform, and an H-bridge is used at the load side to generate bipolar output voltage. The proposed method differs from the presented system in [5] in the following ways: [1] the presented system in [5] is a topology for DC-AC conversion, while the proposed system is a topology for producing an HV uni-polar pulse; and [2] the presented system in [5] includes independent DC sources.In contrast, the suggested solution requires only a single low voltage DC source to charge a series of capacitors, which are then attached in series to discharge in the load by adding high voltage pulses to the water sample.

In this paper the suggested generator designs are for low repeated pulse rate applications, where the load resistance is used as the limiting resistance during the capacitor charging operation. The capacitors are charged sequentially, rather than in parallel as in the Marxgenerator. For a specified load resistance and desired output pulses parameters, detailed designs of the proposed pulse-generators have been presented. To test the proposed principles,

simulation models for the proposed systems were developed.

#### 2. PROPOSED LOW REPETITIVE RATE MODULAR PULSE GENERATOR

The proposed low repetitive rate modular high voltage pulse generator along with its operating technique flow map, are shown in Figure.1. It is made up of 5 series-connected units. As seen in Figure.1b, each module is made up of two IGBTs and a capacitor. By turning on its corresponding Scd switch and turning off its Sb switch, each module's capacitor will become a part of the current direction. By turning on the Sb switch and turning off the Scd switch, the module can be bypassed. Instead of charging all capacitors in parallel, as in the classical approach, the proposed generator would use sequential charging of the capacitors.



#### Figure 1: Proposed nodular high voltage pulse generator (a) Operationalmethodology flow chart and (b) topology

The capacitors can be charged sequentially, then attached in series for discharging using semiconductor switches. It should be remembered that while charging or discharging capacitor,  $S_{cdi}$ should be closed, while Sbi should be closed to keep capacitor floating when charging another capacitor. For egg, C1 can be charged by closing Sy and Scd1, as well as Sb2 to Sb5. All capacitors can be charged using the same principle. As shown in Figure.3, the charging of capacitor (C) must be completed before the discharge operation is performed, i.e., the charging time must be less than or equal to  $(T-t_p)/n$ , where T is the output pulse length,  $t_p$  is the pulse duration, and n is the number of modules. After charging all capacitors, the discharge operation can be started by opening Sy and closing  $S_x$  while keeping all  $S_{edi}$  switches closed. It is important to remember that the load resistance will be involved in the charging process, and it will damp current transients while charging, resulting in low current stresses.





Figure 2: Design of module capacitance



Figure 3: Capacitor variation with charging and discharging (sequential)

The voltage of each capacitor should be held within a particular voltage window  $V_{emin} < V_c < V_{emax}$ at steady state in the proposed setup. It is easy to approximate the proper value of the capacitances, number of units, and input DC voltage for any given output pulse specifications (pulse magnitude Vo, pulse duration T, pulse width t<sub>p</sub>). Gate pulse for each individual semiconductor device during charging and discharging action are summarized in table I.

#### A. During Charging

The capacitor voltage difference during charging can be expressed as in (1), assuming t'=0 at the start of the charging operation [6].

Table 1	Gate pulses	during	charging	and
	discharging	g actior	ı	

	Sx	Sy	$S_{cd1}$	$S_{b1}$	S <sub>cd2</sub>	S <sub>b2</sub>	$S_{cd3}$	$S_{b3}$	$S_{cd4}$	$S_{b4}$	S <sub>cd5</sub>	$S_{b5}$
$C_1 \uparrow$	0	1	1	0	0	1	0	1	0	1	0	1
$C_2 \uparrow$	0	1	0	1	1	0	0	1	0	1	0	1
C3 ↑	0	1	0	1	0	1	1	0	0	1	0	1
C₄ ↑	0	1	0	1	0	1	0	1	1	0	0	1
$C_5\uparrow$	0	1	0	1	0	1	0	1	0	1	1	0
$C_{1:5}\downarrow$	1	0	1	0	1	0	1	0	1	0	1	0

$$V_{c}(t) = V_{dc} + (V_{dc} (b-1) e^{-t/T_{c}})$$

(1)

At the end of charging period  $t' = \frac{T-t_p}{n}$ the voltage must be equal to  $V_{cmax} = (aV_{dc})$  as shown in (2).

$$V_{dc} = V_{dc} + (V_{dc} (b-1) e^{-(T-t_p)/nT_c}$$
(2)

Desired charging time constant can be obtained as in (3) from above expression (3).

$$T_{c} \leq \frac{T - t_{p}}{n \ln (b - 1/a - 1)}$$
(3)

The charging constant is given by (4).

$$T_{c} \le C R_{L} \tag{4}$$

Equating eq. (4) into (3), the capacitance can be expressed as in eq. (5)

$$C \le \frac{T - t_p}{n R_L \ln(b - 1/a - 1)} \tag{5}$$

Charging period for one capacitor is given by (6) t' =  $\frac{T-t_p}{n}$  (6)

#### **B.** During Discharging

The capacitor voltage difference during discharging can be expressed using (7), assuming t=0 at the start of the discharging action [6].

$$V_{c}(t) = a V_{dc} e^{-t/T} d$$
(7)

The voltage must be at least equal to  $V_{emin}$  (=b $V_{de}$ ) at the end of the discharging cycle (i.e., att= $t_p$ ), as seen in (8).

$$V_{c}(t) = bV_{dc} = aV_{dc} e^{-t_{p}/T_{c}}$$
(8)

From above expression, desired time constant can be obtained as shown in (9)

$$^{\mathrm{T}}_{\mathrm{d}} \ge \frac{tp}{\ln\left(a/b\right)} \tag{9}$$

Where  $T_d$  = Discharging period,  $t_p$  = Pulse width (10µs),  $V_o$  = Pulse output voltage (6 kV), T= 0.01s. The discharging time constant is (10).

The capacitance can be expressed as in (11) by substituting (4) for (9).

$$T_{d} = \frac{c}{n} R_{L}$$
(10)

$$C \ge \frac{n t_p}{R_L \ln (a/b)} \tag{11}$$

Based on (5) and (11), the capacitance should be chosen within the range shown in (12).

$$\frac{n t_p}{R_L \ln(a/b)} \le C \le \frac{T - t_p}{n R_L \ln(b - a/a - 1)}$$
(12)

Referring to Figure. 2 depicts the suggested set of capacitances as a function of the number of modules for specified pulse specifications (T,  $t_p$ ,  $R_L$ , a, and b). It is possible to derive an expression for the full number of modules,  $n_{max}$ .

$$n_{\max} = \sqrt{\frac{(T-tp)\ln(a/b)}{tp\,\ln(b-1/a-1)}}$$
(13)

Operating with the maximum number of modules  $(n_{max})$  allows for the lowest possible DC input voltage. Expression (14) gives the equivalent DC input voltage.

$$n_{\max} = \sqrt{\frac{(T-tp)\ln(a/b)}{tp\ln(b-1/a-1)}}$$
(13)

where Vo is the output pulse's amplitude. If the available DC supply is less than  $V_{demin}$ , the suggested topology would entail the use of a boosting stage to raise the input DC voltage to  $V_{demin}$ . When the architecture is based on  $n_{max}$ , the corresponding value of capacitance per module is given by (15).

$$C_{n \max} = \frac{n_{max} tp}{R_L \ln(a/b)}$$
(15)

#### 4. SIMULATION FOR THE LOW REPETITIVE RATE PULSEGENERATOR

To validate the proposed approach, a simulation model of the proposed low-rate pulsegenerator was created. Table 2 lists the system's parameters. The appropriate number of modules, based on the given data and using (13), n will be = 5, while the corresponding input DC voltage and module capacitance, based on equations (14) and (15), will be 1200 V and 0.6433  $\mu$ F, respectively.

In the model, these estimated values are defined, and the simulation results are shown in Figure.4, assuming module capacitors have no pre-charged voltages.

Table 2 Simulation parameter					
Parameter	Value				
Pulse output voltage magnitude, Vo	6 kV				
Pulse width	10 s				
Repetition rate	100 pulse/s (i.e., T=0.01s)				
Load resistance	2.5 k Ω				
Desired capacitor voltage window	$0.95 V_{dc} < V_C < 0.98 V_{dc}$ (i.e., a = 0.98, and b = 0.95)				

Table 2 Simulation parameter

In the model, these estimated values are defined, and the simulation results are shown in Figure.4, assuming module capacitors have no pre-charged voltages. The capacitors are successfully charged in a sequential fashion, and each capacitor voltage is maintained within its given window (0.95 V<sub>dc</sub> < V<sub>c</sub> < 0.98 V<sub>dc</sub>), as shown in Figure 4*a*. The charged capacitors are then connected in series to discharge in the load. The load output voltage is depicted in Figure.4*b*; it is obvious that the output pulses are successfully produced with the desired specifications.

During the generator's start-up period, the output voltage is relatively high during the charging process (due to charging the capacitor with zero pre-charged voltages), indicating a high energy loss. When the capacitor voltages exceed their steady state values, the output voltage during the charging phase is reduced because the original voltage level of the capacitor to be charged  $(=bV_{dc})$  is close to the input voltage level  $(V_{dc})$ , i.e., the voltage difference around the output/charging resistor is negligible, resulting in low energy loss. It should be remembered that there is a limited amount of power dissipated in the load resistance during the charging cycle because it is involved in the charging circuit. The power dissipated during this time is mostly determined by the voltage around the load resistance, which is the difference between the input DC voltage and the capacitor voltage.

By maintaining the capacitor voltage window as close to the value of the DC input voltage as possible (by selecting proper values for a and b close to unity), the voltage around the load resistance will be low during the charging phase, and the resulting dissipated power will be negligible in comparison to the effective power released to the load during discharge.

The currents are depicted in Figure.4c, and d. It is obvious that including the load resistance in the charging and discharging circuits dampens all current spikes. The capacitor voltage seems to be nearly constant, and the supply current is maintained within a specific current window  $(I_{ave}+i)$ .



Figure 4: Simulation result for low-rate configuration; (a) capacitor voltage, (b) Pulsed output voltage, (c) Supply current, and (d) Current of switch Scd in module

It should be noted that, as the given capacitor voltage window narrows (i.e., becomes narrower), the peak-to-peak current ripple  $(2\Delta i)$  decreases as well, and the supply current is almost constant (ripple free) during charging times, but declines to zero during discharging intervals due to the disconnecting

## of the DC input voltage (V<sub>dc</sub>). 5. ITEMS REQUIRED FOR EXPERIMENTAL SET-UP

A potential scaled-down experimental version can be set-up to validate the theoretical high voltage pulse generator. The TITMS320F28335 DSP, for example, is used to produce the gate pulses for the submodule switches in the series A total of 12 submodules (IGBTs) with a capacitance of  $3\mu$ f and a constant voltage of 1200 V are needed. Since the capacitor is the key part of the high pulse generator, we need 5 capacitors with a capacitance of 0.6433  $\mu$ f and a voltage withstand of 1200 V. In order to construct the control circuit, two gate driver boards are also needed.



Figure 5: Experimental reg. [13]

#### CONCLUSION

In this article, a new modular high voltage pulse generator for water treatment applications using underwater pulsed streamer corona discharge is proposed. In the suggested solution, the capacitors are charged sequentially (one by one), and then linked in sequence for discharging. The proposed pulse generator has three major advantages: (i) modularity, (ii) equal distribution of current pressures on the involved semiconductor switches, and (iii) using semiconductor devices with comparatively low voltage ratings to produce high voltage pulsed power. The suggested design is appropriate for applications requiring low repeated pulse rates. In which the water sample's resistance is used as a charging resistance. This work includes a systematic design of the proposed configurations. To demonstrate the feasibility of the proposed method, simulation models have been developed.

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