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Erasmus+ - Key Action 2

Capacity Building within the Field of Higher Education

eACCESS Project

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EU-Asia Collaboration for aCcessible Education in Smart Power Systems

WP 1	PREPARATION
TASK	Preparation of the detailed technical specifications for the physical laboratories (SGPL)
LEAD PARTNER	TUL (Lodz University of Technology, Poland)
PARTICIPATING PARTNERS	RUB(College of Science and Technology, Royal University of Bhutan)

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Contributors	Roshan Chhetri, Namgay Tenzin	
Contact person	Roshan Chhetri	
E-mail address	roshanchhetri.cst@rub.edu.bt	
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1		Roshan Chhetri	Namgay Tenzin
2	25th September 2021	Tomasz Siewierski	
3	24 March 2023	Hari Kumar Suberi	
ETC			

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EXECUTIVE SUMMARY

One of the pillar in eACCESS project is development of Switchgear and Protection laboratory. As a member of eACCESS project supported by Erasmus+, College of Science and Technology, Royal University of Bhutan (RUB) proposes a laboratory focused on Switchgear and Protection. The development of lab is important as most of the graduates joins Power company where protection is important to have a reliable power supply. Electrical Engineering Department of CST, RUB is focus on power system, so the proposed laboratory will be capable to support the same. In this document, the existing laboratory and the proposes laboratory are described. Existing laboratory includes: Electronic Lab, Electrical Machine lab, Power System High Voltage lab, Power System Simulation lab, Instrumentation lab, Power Electronic and Control System lab and Electrical workshop.

Switchgear and Protection laboratory as the proposed laboratory consists of Generator protection relays, distance protection relays, transformer protection relays, feeder protection relays, and Relay test kit. Some of the practical which will be conducted in the proposed laboratory, includes Distance Protection, Directional and non-directional Overcurrent, Undervoltage protection, Transformer Differential Protection, Directional/non-directional Earth fault, Directional and non-directional Overcurrent, Reverse Power Protection, Generator Differential Protection, bus bar protection.

1. INTRODUCTION

College of Scinece and Technology is to become a centre of excellence in science and technology enriched with GNH values. The main mission are to offer internationally recognized programs in science and technology; to generate new knowledge through research and innovation to fulfill the needs; to collaborate with stakeholders and provide expert services; to provide community services to enhance GNH based society.

The University actively encourages and facilitates collaborations between its researchers within the University and with researchers external to it. External researchers seeking to initiate collaboration should partner with a faculty researcher within the University. This is required for international researchers seeking to conduct their research activities within Bhutan through the University. Collaboration is governed by specific administrative polices for collaborations within and outside the University. Moreover, individual Colleges, research centers, and the University as a whole, may develop collaborations with other institutions, in line with its research areas and objectives.

Bhutan has the huge potential for Hydro power spread across the country. Wind and Solar energy are slowly picking up. Protection system is part of whole power system. For reliable power, generator protection, transmission line protection, transformer protection, bus bar protection, feeder protection are important components. The graduates need sound knowledge in protection system as majority are get employed in Druk Green Power Corporation (Generating company), Bhutan Power Corporation (Transmission and Distribution Company), Bhutan Electricity Authority and Industries. Switchgear and Protection Laboratory will uplift the graduates with sound knowledge.

2. DESCRIPTION OF EXISTING LABORATORIES

The Electrical Engineering Department, College of Scienece and Technology, Royal University of Bhutan has following laboratory for undergraduate Program:

2.1 Electronics Laboratory:

This physical laboratory space hosts practical activities for two subjects: Electronics and Circuit Theory and thus it is divided into three parts Electronics I, Electronics II and Circuit Theory I. The objective of the Electronics laboratory is to give students the opportunity to conduct practical experiments with basic electronic components, learn operational characteristics of basic electronic circuits, as well as acquire skills in the design, assembly and testing of electronic devices. The objective of the Circuit Theory Laboratory is to convert the theory into hands-on experience with simple electrical circuits (DC and AC) and experimental verification of the fundamentals of Ohm's, Kirchhoff current and voltage laws.

2.2 Electrical Machine Laboratory:

This laboratory is divided into two parts: Electrical Machine I (dc Part) and Electrical Maachine II (ac part) . The objective of this laboratory is to familiarize students with designs and operational characteristics of the basic electrical machines, which are key components of the transmission and the distribution network. The students validate in practice operational characteristics of various electrical machines including DC separately excited machine, different types of DC generators. Students learn how to determine with practical tests technical parameters of the single-phase transformer and induction motors. They perform the control of three phase AC generator, wound rotor induction motor. They prepare voltage characteristics and perform synchronisation of three-phase synchronous generator. They exercise parallel operation of power transformers, as well as parallel operation of AC generators.

2.3 Power System High Voltage Laboratory:

The objective of this laboratory is to give students the opportunity to conduct electrical tests on materials and power system apparatus.

2.4 Power System Simulation Laboratory:

This is a computer laboratory and the objective of this laboratory is to familiarize students with professional software package for key power system and grid calculations, to give students the opportunity to prepare and run simulation experiments and analyse the results and influence of the selection of models and simulation parameters.

2.5 Instrumentation Laboratory:

The objective of this laboratory is to familiarize students with instrumentation, measurement techniques and data analysis and allow them to perform laboratorial work in the other electrical laboratories and workshops.

2.6 Power Electronic Electronics and Control Systems Laboratory:

This physical space hosts two laboratory units, Power Electronic Laboratory and Control Laboratory. The objective of the Power Electronic Laboratory is to expose students to operation and characteristics of power semiconductor devices and passive components, their practical application in power electronics, to provide a practical exposure to operating principles, design and synthesis of different power electronic converters, to introduce students to industrial control of power electronic circuits as well as safe electrical connection and measurement practices. The objective of the Control Laboratory is to give the students opportunity to investigate in practical implementation various controller design principles, to develop controllers for a set of hardware and software applications.

2.7 Electrical workshop.

The objective of this laboratory is to give students the opportunity to develop practical skills necessary for the implementation and maintenance of basic electrical circuits, devices and system.

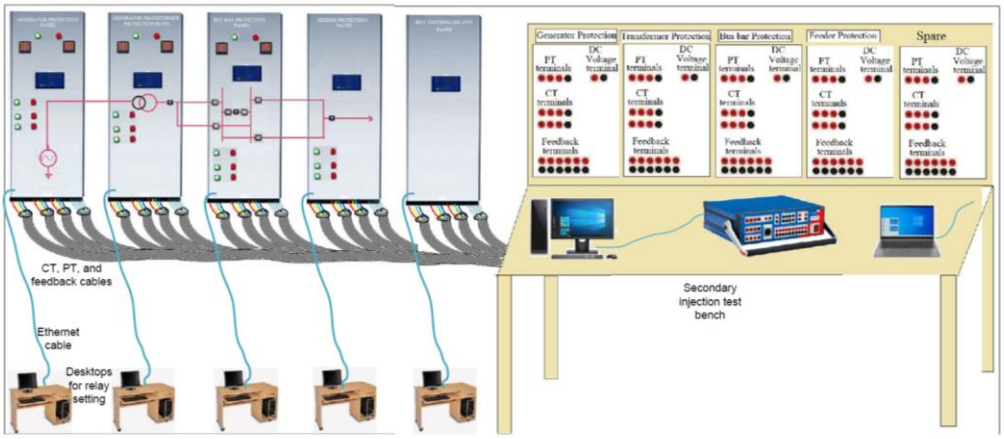
3. DESCRIPTION OF PROPOSED LABORATORIES

The SGPL (Switchgear and Protection Laboratory) will be set up at Electrical Engineering Department, College of Scinece and Technology, Royal University og Bhutan with the support from eACCESS project. This will be first of its kind in the country. The proposed laboratory consists of Generator protection relays, distance protection relays, transformer protection relays, feeder protection relays, and Relay test kit. Some of the practical which will be conducted in the proposed laboratory, includes Distance Protection, Directional and non-directional Overcurrent, Undervoltage protection, Transformer Differential Protection, Directional/non-directional Earth fault, Directional and non-directional Overcurrent, Reverse Power Protection, Generator Differential Protection, bus bar protection.

4. PROPOSED LIST OF EQUIPMENTS

The proposed SGPL (Switchgear and Protection Laboratory) will have follwoing equipment.

1. Generator protection relay –
2. Bus bar protection
3. Transformer differential protection
4. Feeder protection (Multifunction Protection Relay-Overcurrent and Earth Fault Protection)
5. Transmission line protection relay (Distance Protection relay)



Note: This drawing is just to show overall layout. The components, materials, and location on the panels will be as per the approved drawings

Proposed lay out of the lab equipment

List of practical

Experiment No: 1. Study the construction of Protection equipment

Experiment No: 2. To perform relay performance of Over-current protection

Experiment No: 3. To study performance of Transformer Differential Realy

Experiment No: 4. To study performance of Transformer Directional Realy

Experiment No: 5. To study performance of Generator protection Realy

Experiment No: 6. To study performance of transmission protection Realy (Distance Protection, Directional and non-directional Overcurrent, Undervoltage protection)

Experiment No: 7. To study performance of feeder protection Realy

Experiment No: 8. To study performance of busbar protection Realy

Experiment No: 1. Study the construction of Protection equipment

Aim: To study the constructional features of various protection equipment (Current Transformer, Capacitive voltage transformer, Voltage transformer, Relays, Circuit Breaker(

Objectives

- Study the construction of each equipment
- Identify various parts of each equipment

Experiment No: 2. To perform relay performance of Over-current protection

Aim: To study the performance of over current protection

Objectives

Sl. No	**Protection function of Transmission line**
1	Directional and non-directional Overcurrent
2	Directional and non-directional Earth fault
3	Circuit Breaker Failure

Experiment No: 3. To study performance of Transformer Differential Relay

Transformers are one of the most costy equipment in electrical power systems. Any typesof internal faults are a risk for all transformers, with short-circuits dissipating the highest localised energy. Unless cleared quickly, the possibility of rewinding will diminish and core damage may become irreparable.

Aim: To study the performance of Transformer Differential Relay for protection

Objectives: To study some of the follwiong functions

Sl. No	**Protection function of Transformer**
1	Transformer Differential Protection
2	Restricted Earth Fault (REF) Protection
3	Sensitive Earth Fault (SEF) Protection
4	Instantaneous Ground Overcurrent
5	Breaker Failure

-

Experiment No: 4. To study performance of Transformer Directional Relay

Aim: To study the performance of Transformer directional relay

Objectives

Sl. No	**Protection function of Transformer**
1	Directional/non-directional Earth fault
2	Instantaneous Phase Overcurrent
3	Instantaneous Ground Overcurrent
4	Breaker Failure

Experiment No: 5. To study performance of Generator protection Realy

Aim: To study the performance of Generator protection

Objectives: To study some of the follwoing functions

Sl. No	Protection function of Generator
1	Generator Differential Protection
2	Negative Phase Sequence Protection
3	Reverse Power Protection
4	Low Forward Power Protection
5	Generator Over Voltage Protection
6	Generator Under Voltage Protection
7	Generator Over Frequency Protection
8	Inverse Time Overcurrent
9	Instantaneous Phase Overcurrent
10	95% Stator Earth Fault Protection
11	100% Stator Earth Fault Protection
12	Loss of Excitation Protection
13	Pole Slipping Protection
14	Generator Backup Impedance Protection
15	Rotor Earth Fault Protection
16	Breaker Failure

-

Experiment No: 6. To study performance of transmission protection Realy (Distance Protection, Directional and non-directional Overcurrent, Undervoltage protection)

Aim: To study performance of transmission protection Realy

Objectives: To study some of the following functions

Sl. No	Protection function of Transmission line
1	Distance Protection
2	Differential Protection
3	Directional and non-directional Overcurrent
4	Negative sequence Overcurrent
5	Broken Conductor detection
6	Directional and non-directional Earth fault
7	Circuit Breaker Failure

Experiment No: 7. To study performance of feeder protection Realy

Aim: To study the performance of feeder protection Realy

Objectives: To study some of the follwoing functions

Sl. No	**Protection function of Feeder**
1	Distance Protection
2	Directional and non-directional Overcurrent
3	Negative sequence Overcurrent
4	Broken Conductor detection
5	Directional and non-directional Earth fault
6	Circuit Breaker Failure

Experiment No: 8. To study performance of busbar protection Realy

Aim: To study performance of busbar protection Realy

Objectives: To study some of the follwoing functions

Sl. No	**Protection function of centralized Busbar**
1	Busbar protection
2	Breaker failure
3	Earth fault
4	Numbers of bays: minimum 4

5. FINAL REMARKS

This is a new types of lab which is not very common. This laboratory will give sound knowledge to the graduates who can make best use once they join company like Druk Green Power Corporation, Bhutan Power Corporation, and many industries in the country. Once the initial procurement is done and laboratory set up, depending on the budget available, additional equipment will be procured for the development of lab.

Note: Complete manual can be developed only after we receive the equipment and training

TECHNICAL SPECIFICATIONS FOR SWITCHGEAR AND PROTECTION LABORATORYU, IEC 61850 WITH GENERATOR, TRANSFORMER, BUS BAR & FEEDER PROTECITON NUMERICAL RELAYS AND OMICRON TEST KIT

1. Scope:
   1.1. This specification covers design, manufacture, assembly, testing before supply, inspection, packing and delivery of numerical relays for the generator, transformer, motor, feeder and bus bar protection.
   1.2. The preferable brands are GE, Siemens, ABB, Schneider
   1.3. The relays manufactured should conform to the relevant standards and of highest quality of engineering design and workmanship. The equipment manufactured shall ensure satisfactory and reliable performance throughout the service life.

2. Service Conditions:
   2.1. Climatic Conditions:

Equipment supplied against the specification shall be suitable for satisfactory operation under the following tropical conditions:

Max. ambient air temperature	45 ° C
Max. relative humidity	100 %
Max. annual rainfall	3500 mm
Max. altitude above mean sea level	690 mtrs.
Isoceraunic level	45
Reference Ambient Temperature for temperature rise	60 ° C
Climatic Condition	Moderately hot and humid tropical climate conducive to rust and fungus growth

The climatic conditions are prone to wide variations in ambient conditions and hence the equipment shall be of suitable design to work satisfactorily under these conditions.

3. Applicable Standards:
   3.1. Unless otherwise specified all equipment and material shall conform to the latest IS/IEC applicable standards. Equipment complying with other internationally recognized standards will also be considered if it ensures performance equivalent

or superior to Indian standards. In the event of supply of equipment conforming to any international / internationally recognized standards other than the standard listed below.

3.2. All the relays provided under the specification shall generally conform to the latest issues of the following:

a)	IS 12063/1987	Degree of Protection provided for enclosure of electrical equipment.
b)	IS 5/2004	Color for ready mixed paints & enamels.
c)	IS 3231 / 1986 & 1987	Electrical relays for power system protection
d)	IEC 60255	Numerical protection relay
e)	IS 1248/2003	Indicating instruments
f)	IEC 61850 Edition I & II	Communication Protocol for RELAYs.

4. GENERALREQUIREMENT OF NUMERICAL RELAYS:

The relay in general shall comply with the all the requirements mentioned in general requirements below.

4.1. Numerical multifunctional combined microprocessor-based generator, transformer, motor, bus bar and feeder protection relays will have all the protection functions along with disturbance record for fault analysis.

4.2. The numerical relay must have an IEC 61850 Edition I & II.

4.3. All PCB used in relays should have harsh environmental coating as per standard IEC 60068 (HEC) to increase the particle repellence and thereby increasing the life of relay. Relay shall be manufactured using lead- free components.

4.4. The relays shall provide an operating range of -10°C to 60°C and be tested as per IEC 60068.

4.5. The relays shall have a USB/RS232/RJ45 communication port for connecting to a local PC/Laptop for setting and viewing the data from the relay.

4.6. The relay shall be provided with 1 set of common support software compatible with Windows 10 which will allow easy uploading of settings of relay in addition to downloading of event, faults, disturbance records, measurements.

5. TYPE TESTS:

Offered relay must be type tested for the following tests:

S.N	Type Test	Test Specification
1	Performance test	
1.1	Measurement accuracy of characteristic quantity and specified time	IEC 60255-1
1.2	Limits of operating range of auxiliary energizing inputs and auxiliary voltage dependence	IEC 60255-1
1.3	Limits of frequency range and frequency dependence	IEC 60255-1
1.4	Limits of ambient temperature and ambient temperature dependence	IEC 60255-1
2	Rated burden requirement	
2.1	Measuring circuits	IEC 60255-1
2.2	Auxiliary circuits	IEC 60255-1
2.3	Signaling inputs	IEC 60255-1
3	Thermal requirements	
3.1	Maximum allowable temperature	IEC 60255-27
4	Power supply requirements	
4.1	Voltage dips to dc auxiliary voltage	IEC 60255-26
4.2	Interruptions to dc auxiliary voltage	IEC 60255-26
4.3	Ripple in dc auxiliary voltage	IEC 60255-26
4.4	Voltage dips to AC auxiliary voltage	IEC 60255-26
4.5	Interruptions to AC auxiliary voltage	IEC 60255-26

6. Training:

Suitable training to be imparted to CST's persons on the following items:

a) Relay setting and parameterization

b) Relay configuration with respect to I/P, O/P and functional block for protection.

c) Diagnostic features for disturbance records.

7. TECHNICAL REQUIREMENTS FOR NUMERICAL RELAY:

The following are the technical requirement of feeder protection relay

7.1. **Purpose and application:**

The purpose and application of the relays and other components are to setup a Protection Relay Laboratory for carry out the testing of all type of protection functions applied in the industries.

7.2. **Main Protection functions: It could be either (Siemens/GE Alstom/ Schneider). Wherever possible model number is mentioned.**

7.2.1 Generator protection relay (P343916A6M0380M /7UM85/MiCom, P345)

Sl. No	Protection function of Generator
1	Generator Differential Protection

2	Negative Phase Sequence Protection
3	Reverse Power Protection
4	Low Forward Power Protection
5	Generator Over Voltage Protection
6	Generator Under Voltage Protection
7	Generator Over Frequency Protection
8	Inverse Time Overcurrent
9	Instantaneous Phase Overcurrent
10	95% Stator Earth Fault Protection
11	100% Stator Earth Fault Protection
12	Loss of Excitation Protection
13	Pole Slipping Protection
14	Generator Backup Impedance Protection
15	Rotor Earth Fault Protection
16	Breaker Failure

7.2.2 Transformer Protection Relay (P64292AA6M0070P/(7SR54) (87T)/MiCom, P643,)

Sl. No	**Protection function of Transformer**
1	Transformer Differential Protection
2	Restricted Earth Fault (REF) Protection
3	Sensitive Earth Fault (SEF) Protection
4	Directional/non-directional Earth fault
5	Instantaneous Phase Overcurrent
6	Instantaneous Ground Overcurrent
7	Breaker Failure

7.2.3 Transmission Line Protection Relay (P54391NA7M0820M/7SA87 (87L+21))

Sl. No	**Protection function of Transmission line**
1	Distance Protection
2	Differential Protection
3	Directional and non-directional Overcurrent
4	Negative sequence Overcurrent
5	Broken Conductor detection
6	Directional and non-directional Earth fault
7	Circuit Breaker Failure

7.2.4 Feeder Protection Relay (P14191AN6M0520J/7SR1/MiCom, P443)

Sl. No	**Protection function of Feeder**
1	Distance Protection
2	Directional and non-directional Overcurrent
3	Negative sequence Overcurrent

4	Broken Conductor detection
5	Directional and non-directional Earth fault
6	Circuit Breaker Failure

7.3. Centralized Busbar Protection Relay (P746916K6M0120M/)

Sl. No	**Protection function of centralized Busbar**
1	Busbar protection
2	Breaker failure
3	Earth fault
4	Numbers of bays: minimum 4

7.4. Other General feature requirements for all relays

Sl. No	**Features**	**Requirements**
1	Auxiliary Supply	220 VDC or 230 V AC
2	HMI	Large display for user defined to display of single line diagram (graphical data)
3	LED indications (Minimum)	3 Fixed 8 Assignable at site
4	PT input Voltage	110 V AC
5	CT input	5A / 1A (Site selectable)
6	Binary Inputs (minimum)	8 Nos
7	Binary outputs (minimum)	8 Nos
8	Mounting type	Rack mounting
9	Fault record	Relay shall have facility to store at least last 100 time-stamped fault records with information on cause of trip, trip values of electrical parameters.
10	Disturbance records	The relay shall have capacity to store at least 20 sec disturbance record waveforms.
11	Rated frequency	50 Hz
12	Relay software	Necessary software for relay setting, retrieving DR, event log, trip log should be supplied by the Manufacturer. The License of the software is to be issued to APDCL for the entire lifespan of the relay.
13	Manuals, Drawings and Literature	1. The relays should be supplied with manuals with all technical and operating instructions. 2. All the internal drawings indicating the logics and block diagram details explaining principle of operation should be given at the time of supply.

8. PANELS AND MOUNTING

i) The panels shall be provided with mounting plates for rack-mounting of the relays. The quantity of panels will be 5 numbers and mounting plates should be sufficient to make a rack for 5 relays.

j) All panels should installed racks for mounting the relays mentioned above (one relay per panel)

The panel specifications are provided in the table below:

SN	DESCRIPTION	Qty.	UoM
1	PS Spl enclosure of 600WX1400HX700D Front single leaf door (2mm thk sheet) with 3-point locking system and RH side hinges. Rear single leaf door (2mm thk sheet) with 3 point locking system and RH hinges. Mounting plate CRCA 3mm thk with painted RAL7035txt colour. Top cover (1.5 mm thk sheet) and 4 nos of eye bolts. Bottom cover (1.5 mm thk sheet) with 3 part gland plates (3mm thk sheet GI). Assembled Acessories C-Plinth, 3mm thk, RAL7022Tex - SPL -1EA 15mm thk AVP - SPL - 1EA **Note : Color of the enclosure- internal dip coat and external powder coated with RAL7035Txt, Plinth- RAL7022txt	5	No.

9. SECONDARY INJECTION TEST KIT (Omicron test kit CMC 365 Essential)

The testing kits should be able to connect to computer via Ethernet cable as specified below. All the amplitude, phase and frequency (adjustable frequency range up to 3kHz with a phase angle of 0-360 degrees.) of the voltage and current should be able to change in the computer. The hardware and software requirement for the testing kit are given below:

9.1 Specification for Hardware parts

Sl. No	Features	Requirements
1	Power supply	230 V AC, 50Hz
2	Voltage output of test quantities	3 phase voltage of 0V to 300 V AC, 50 Hz with neutral
3	Current output of test quantities	Two galvanically separated three-phase current outputs current should be variable from 10 to 20 A with frequency variable from 0 to 60 Hz
4	DC voltage supply to test object	**DC voltage variable** 0 ... 66 VDC (max. 0.8 A) 0 ... 132 VDC (max 0.4 A) 0 ... 264 VDC (max. 0.2 A)
5	Binary input	**1. Minimum 4 Nos** 2. **Trigger criteria:** Potential-free or DC-voltage compared to threshold voltage

6	Binary output	**1. Minimum 4 Nos** 2. **AC Loading :** Vmax 300 V AC, I max 6 3. **DC loading :** Vmax 300 V AC, I max 6
7	Ethernet Ports	**1. Type:** 10/100Base-TX (10/100Mbit, twisted pair, auto MDI/MDIX or auto-crossover) 2. **Connector:** RJ45 3. **Cable Type:** LAN cable of category 5 (CAT5) or better 4. **Status indication:** Green for link and Yellow for traffic
8	Operating temperature	Same as relays
9	Shock and Vibration	Tested according to IEC 60068-2-6 and IEC 60068-2-27
10	Wiring Accessories	1. Flexible test lead of 2 meters = 12 Nos. 2. Flexible jumpers: 8 nos 3. Flexible terminal adapter: 12 pieces 4. Flexible test lead adapter: 12 Nos 5. Cable Lug adapter: 20 pieces (for 2.5 mm sq)
11	Test kit should have capability of protection testing with IEC 61850 devices	

9.2 Specification for software

The software should have following packages and software modules that can be used independently from each other for single tests.

i) Convenient manual testing
j) State sequencer
k) Ramping (Magnitude, phase, frequency)
l) Pulse ramping
m) Overcurrent (positive, negative and zero sequence overcurrent characteristics)
n) Distance (impedance evaluation)
o) Advance distance
p) Single-phase differential
q) Playback of COMTRADE files
r) The license should be valid for any desktop connect to the test kit.

10. COMPUTER

Dell OptiPlex 3280 All-in-One
Processor - i5-10500T
RAM - 8GB
Storage - 500GB
Dell KB216 Keyboard
Dell Optical Mouse - MS116
Power Supply: 230 VAC, 50Hz

11. Laptop

HP Spectre x360 15t-eb100
Color: Nightfall Black

Intel® Core™ i7-1165G7
15.6" Diagonal 4K UHD Display
16 GB RAM
1 TB NVMe™ M.2 SSD
with HP Rechargeable MPP2.0 Tilt Pen
and Belkin USB-C 11-in-1 Multiport Dock INC004btSGY
Power Supply: 230 VAC, 50Hz

12. GTP

Sl. No	Items and requirements	Details to be filled by supplier as per the offer	Qty
1	**Line Differential Protection with Inbuilt Distance Protection**	1	
	1.1 Make/Brand/Manufacturer		
	1.2 Relay Model No.		
	1.3 Power supply		1
2	**Transformer Protection Relay**	1	
	2.1 Make/Brand/Manufacturer		
	2.2 Relay Model No.		
	2.3 Power supply		1
3	**Multifunction Protection Relay-Overcurrent and Earth Fault Protection (Feeder)**		
	3.1 Make/Brand/Manufacturer		
	3.2 Relay Model No.		
	3.3 Power supply		1
4	**Generator Protection**		
	4.1 Make/Brand/Manufacturer		
	4.2 Relay Model No.		
	4.3 Power supply		1
5	**Bus bar Protection**		
	5.1 Make/Brand/Manufacturer		
	5.2 Relay Model No.		
	5.3 Power supply		1
6	**Bay Control Unit - C264**		
	Deatils		
			1
7	Omicron test kit CMC 365 Essential		
	7.1 Make/Brand/Manufacturer		
	7.2 Model No.		
	7.3 Power supply		1

8	Desktop		4
9	Laptop		1
10	Cubicle, simplex		As required for all relays