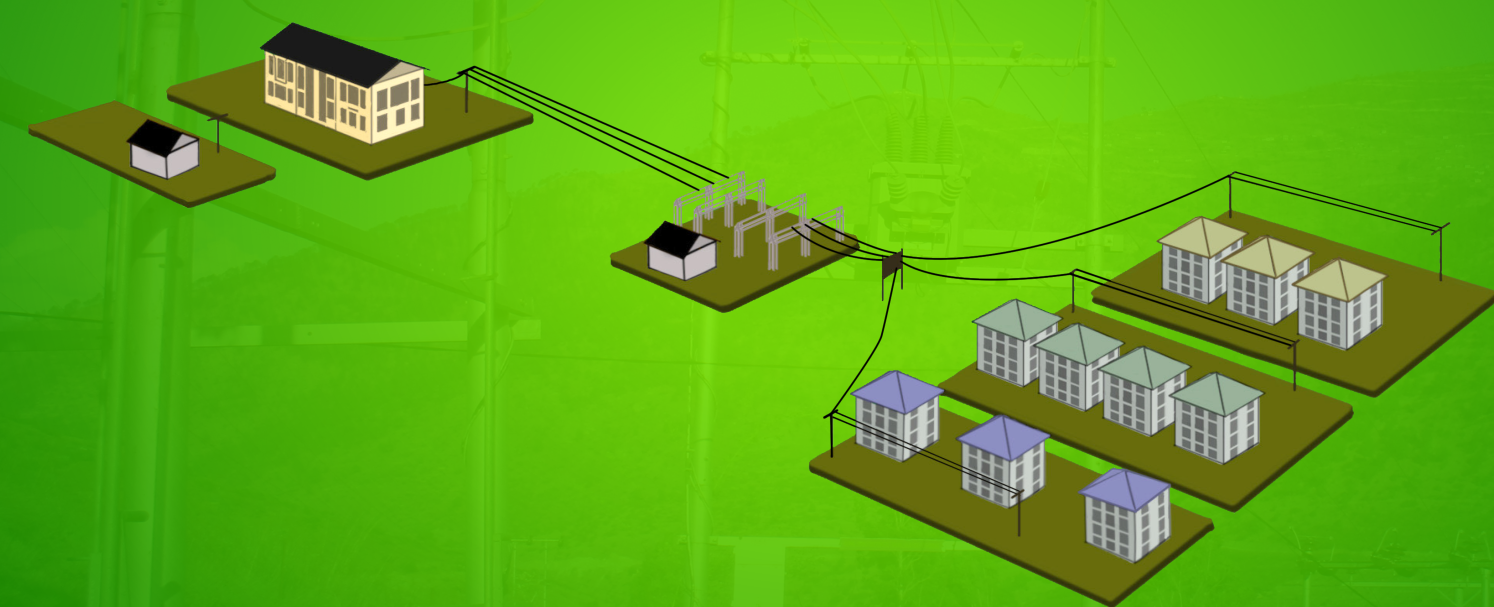
DISTRIBUTION SYSTEM MASTER PLAN (2020-2030)

PARO DZONGKHAG



Distribution and Customer Services Department
Distribution Services
Bhutan Power Corporation Limited

2020

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FOREWORD

The Distribution System Master Plan (DSMP) identifies, prioritizes and opts for adequate and optimal distribution system expansion and augmentation programs to meet the expected electricity growth and demand development in the Country. This timely formulation of DSMP is in line with the stated corporate strategic objective of providing affordable, reliable and quality services to customers and will enable to traverse the changing technological, regulatory and social constraints for the time horizons considered.

The DSMP has been finalized after a series of consultative discussions with all the relevant stakeholders to obtain a shared outcome. In particular, adequate efforts have been taken to ensure that the DSMP aligns and integrates with the stated plans and programs of the Royal Government of Bhutan (RGoB) for the energy sector.

Based on the expected demand development for the time horizons considered, the DSMP outlines the road map for the implementation of optimized distribution network expansion programs and projects in stages with the expected investment required and financial commitments. The DSMP will be updated on a regular basis to incorporate changing business imperatives and contexts to ensure its relevance.

Appreciation goes to all the officials of the Distribution Services for formulating and coming out a comprehensive document that is timely which will serve as a blueprint for the Distribution Services to build a robust distribution system that will go a long way in contributing towards realization of BPC's objectives of providing a reliable electricity supply to its valued customers.

(Sonam Tobjey)
Chief Executive Officer

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Abbreviations

BPC: Bhutan Power Corporation Limited
ESD: Electricity Services Division
DSMP: Distribution System Master Plan
GIS: Geographical Information System
SLD: Single Line Diagram
ETAP: Electrical Transient and Analysis Program
IS: Indian Standard on Transformers
IEC: International Electrotechnical Commission
DT: Distribution Transformer
TSA: Time Series Analysis
LRM: Linear Regression Method
MV: Medium voltage (33kV, 11kV and 6.6kV (if it exists))
DDCS: Distribution Design and Construction Standards
kVA: Kilo Volt Ampere
W: Watt
kWh: Kilo Watt Hour
RMU: Ring Main Unit

PHCB: Population and Housing and Census of Bhutan
BDBL: Bhutan Development Bank Limited
BNB: Bhutan National Bank
RSTA: Road Safety and Transport Authority
RICB: Royal Insurance Corporation Limited
BoB: Bank of Bhutan Limited
USS: Unitized Substation
DMS: Distribution Management System
ADMS: Advanced DMS
SCADA: Supervisory Control and Data Acquisition
DSCADA: Distribution SCAD

Definitions

Asset Life: The period of time (or total amount of activity) for which the asset will be economically feasible for use in a business.

Balanced system: A system is said to be balanced when all phase conductors carry approximately the same current. For delta systems, this applies to two-phase conductors, and for three-phase wye systems, this applies to three-phase conductors.

Contingency plan: Power that is needed when regularly used electric generating units are not in service, such as during short-term emergencies or longer unplanned outages, and during periods of scheduled maintenance when the units must be shut sown. Short-term backup power is generally called emergency power. Long-range backup power is often provided for in reserve sharing agreements.

Capacity: Also known as the power or capability of an electric generating plant. Facilities and place to serve electric customers. 2) The total amount of electrical energy a power line is able to transport at any given time (Measured in kVA).

Clearance: The clear distance between two objects measured surface to surface. For safety reasons, proper clearance must be maintained between power lines and the ground, buildings, trees, etc.

Critical Value: The value of the random variable at the boundary between the acceptance region and the rejection region in the testing of a hypothesis.

Distribution line: That part of the electrical supply system that distributes electricity at medium voltage (33kV, 11kV & 6.6kV) from a transformer substation to transformers or other step-down devices service customer premises, which finally supply power at the voltage required for customer use.

Distribution loss: Energy losses in the process of supplying electricity to the consumers due to commercial and technical losses.

Distribution system: The portion of the transmission and facilities of an electric system that is dedicated to delivering electric energy to an end-user.

Energy: Delivered power measured in kilowatt-hours (kWh).

Generating station: A plant wherein electric energy is produced by conversion from some other forms of energy.

Grid: A system of high-voltage transmission and power-generating facilities that is interconnected with a number of other bulk power supply agencies on a regional basis. A grid enables power to be transmitted from areas having a surplus to areas experiencing a shortage. A grid also eliminates some duplication of costly facilities in a given region.

Investment: the action or process of investing money for certain activities with return and profit.

Lines (electrical supply) - Those conductors used to transmit or deliver electric energy and their necessary support or containing structures.

Linear Regression Method: In **statistical modeling**, regression analysis is a set of statistical processes for **estimating** the relationships between a **dependent variable** (often called the 'outcome variable') and one or more **independent variables.**

Load: 1) A device, or resistance of a device, to which power is delivered in a circuit. 2) The measure of electrical demand placed on an electric system at any given time.

Load forecasting: The methods used in determining a system's short and long-term growth in peak load and kilowatt-hour sales by consumers.

Load Growth: The increase in the demand of power required over time.

Marginal Value: Just barely adequate or within a lower Limit.

On line - Term generally used to indicate when a generating plant and transmission line is scheduled to be in operation. When an operational plant and line is not on line, it is said to be "down."

Outage - Interruption of service to an electric consumer.

Overload - Operation of equipment in excess of normal, full-load rating, or of a conductor in excess of rated ampacity that, when it persists for a sufficient length of time, would cause damage or dangerous overheating. A fault, such as a short circuit or ground fault, is not an overload.

Optimization: the action of making the best or most effective use of a situation or resource.

Pad-mounted equipment- General term describing enclosed equipment, the exterior of which enclosure is at ground potential, positioned on a surface-mounted pad. Example: underground transformers and junction boxes.

Peak demand - The maximum amounts of electricity used by a utility customer at any given time during the year. The peak is used to measure the amount of electric transmission, distribution, and generating capacity required to meet that maximum demand, even if it occurs infrequently and only for very short durations.

Peak load - The greatest amount of electricity used during a time period by the consumers in a utility's system.

Power - The time rate of electric energy in a device or circuit, measured in watts.

Power factor - A measurement of efficiency in the use of electricity. For example: a 100% power factor would be like a horse pulling a wagon on rails directly forward with no resistance. If the horse turns and pulls at a right angle to the rails, he may pull just as hard, but his efforts will not move the car. This would be a zero percent power factor. Now, if he pulls at a 45-degree angle to the rails, he will pull the car, but not with as high efficiency as if he were pulling straight down the rails. In the use of electricity, not every kilowatt generated translates into equivalent horsepower efficiency.

Power grid - A network of generation, transmission and distribution system that are interconnected

Power quality - The extent to which a utility system is able to maintain its delivery of electric energy within the tolerable limits of voltage and without outages or other problems with affect a customer's equipment use.

Power supply - Source of current and voltage.

Reliability - A measure of a utility's ability to deliver uninterrupted electric service to its customers.

Substation - An electrical facility containing switches, circuit breakers, buses, and transformers for switching power circuits and transforming power from one voltage to another, or from one system to another.

Time Series Analysis: The statistical techniques used when several years' data are available to forecast the load growth.

1. Executive Summary

Bhutan Power Corporation Limited is mandated to provide affordable, adequate, reliable and quality electricity services to the customers through transmission and distribution network established across the country. Towards realizing the mission, vision and destination statement of BPC as outlined in the Corporate Strategic Plan (2020-2030), there is a need to carry out comprehensive studies of the distribution system to address the system deficiencies as the ground realities are different triggered by technological advancement and economic growth.

The existing distribution networks are modeled and accordingly, the technical evaluation is carried out adopting the generally accepted load forecasting framework i.e. Time Series Analysis in conjunction to Linear Regression Method, the power requirement for next ten (10) years are forecasted. Subsequently, the network capability and the system gaps are identified with proposed distribution system planning. The investments are proposed (based on the priority matrix) to address the system inadequacies with the intent to improve the Customer Services Excellence, Operational and Resource Optimization Excellence, Innovation and Technology Excellence and Business Growth Excellence.

The single to three-phase distribution network conversion across the country is reproduced in this report based on the studies carried out by BPC "Technical and Financial Proposal on Converting Single Phase to Three-Phase Power Supply in Rural Areas".

The details on the distribution grid modernization are outlined in Smart Grid Master Plan 2019 including the investment (2020-20230). The identification of the system deficiencies and qualitative remedial measures which would require system automation and remote control as per the existing and projected load are only outlined in this report.

Similarly, the system study beyond the Distribution Transformers had to be captured during the annual rolling investment and budget approval.

The ETAP tool is used to carry out the technical evaluation and validate the system performances. Finally, necessary contingency plans, up gradation and reinforcement plans are proposed as annual investment plans based on the outcome of the simulation result.

2. Introduction

The system study is intended to improve the power distribution system in Bhutan by formulating a comprehensive, national level and district wise DSMP (2020-2030) till 2030 that provides measures for renewing and reinforcing power distribution facilities. BPC's distribution system has grown in size and complexities over the years. While many network additions and alterations carried out so far were as per the recommendations of the Druk Care Consultancy Study Report (2006), the ground realities are evermore different now than anticipated during the study. There is a need to explore opportunities for optimizing the available resources and develop a master plan for future investments.

Some of the prominent driving factors required for the development of the master plan includes but not limited to reliable power supply to the customers, reduction of distribution losses, network capability with the anticipated load growth, optimization of the resources and to develop annual investment plan.

BPC has never carried out comprehensive system studies to improve the distribution system and optimize the available resources. The recurring investment plans (annual) is based on the on-site and field proposals without any technical evaluation being carried out which could have resulted in preventable and excessive investments. Therefore, proper planning is necessary to improve the system for optimal usage of resources.

It is also intended that this master plan is to provide general guidance in preparing long-range system planning. The analysis indicates where up-grades are most likely to be economical and provides insight into the development of a practical transition from the existing system to the proposed long-range system. Based on this analysis, recommendations are made for improving system performance and increasing system capacity for expansion. Periodic reviews of the master plan will be required to examine the applicability of the preferred plan considering actual system developments.

3. Objectives of the Master Plan

The objective(s) of the DSMP (are):

3.1 To carry out the system study of the existing distribution network, forecast and come out with the comprehensive ten (10) years strategic distribution plan;

3.2 To provide affordable and adequate electricity, reduce losses, improve power quality, reliability, optimize the resources and gear towards excellent customer services; and

3.3 To come out with annual investment plans.

4. Scope of the Distribution System Master Plan

Formulation of detailed DSMP (2020-2030) of the Dzongkhag for renewal, reinforcement, and extension of the power distribution system up to DT.

5. Methodology and Approach

In order to better understand the existing distribution system and postulate the credible investment plans; standard framework and procedures had been adopted. However, in the absence of any standardized procedures in BPC for planning of distribution system, the following customized procedures detailed in **Section 5.1** through **Section 5.5**and as shown in **Figure 1** are considered to suit BPC's requirement for developing the DSMP.

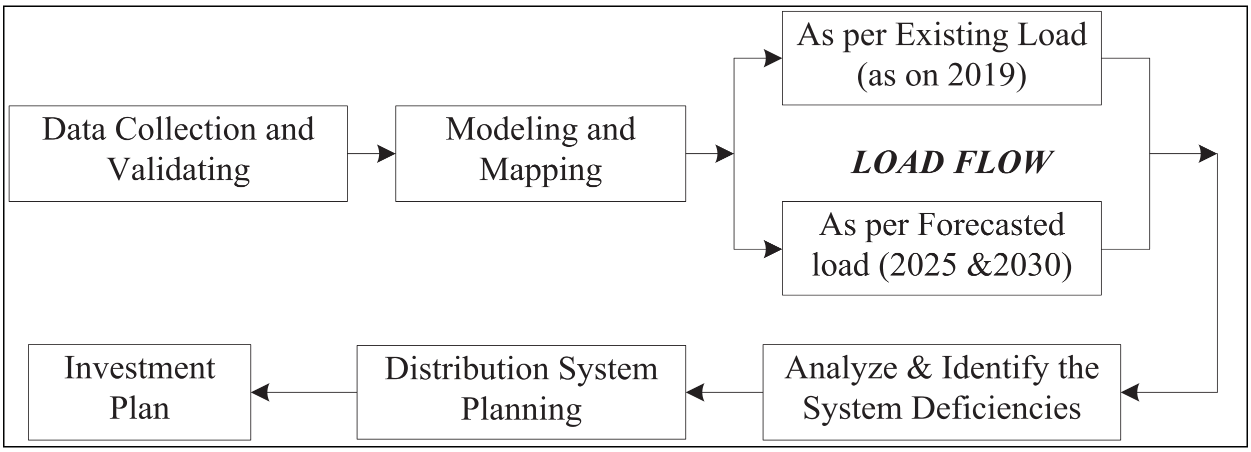


Figure 1: Block diagram for distribution system planning for thematic studies

5.1 Data Collection and Validation

In order to carry out the detailed studies with greater accuracy, complete and reliable data for the existing distribution infrastructure is required. Therefore, intensive field investigation was carried out during the months of April and May (2020) to validate the information that was collected. The information required for the studies does not confine to the BPC's internal distribution network but also the developmental activities of the cross-governmental sectors. The power arrangement requirements from these developmental activities were also used to forecast the power demand. The data validation on the distribution system includes the review of all the power sources, medium voltage lines and transformers with that of GIS data of Environment and GIS Division and SLD submitted by respective ESDs which is attached as **Annexure-1.**

5.2 Modeling and Mapping

The feeder wise distribution lines and transformers were modeled and mapped in ETAP tool and the base case was developed for the existing distribution network. The technical parameters for the lines and transformers were considered based on IS 2026, IEC 60076 (Details attached as **Annexure-2**) to develop the base model. Modeling and Mapping detail is attached as **Annexure-1.**

5.3 Analysis and Identification of System Deficiencies

The existing distribution system model was analyzed in the ETAP involving balanced load flow to figure out the network capabilities against the set distribution standards. The load growth was projected using the commonly adopted methodology that is LRM in conjunction to TSA which is based on the historical data and accordingly the behavior of the distribution system was analyzed, and the system deficiencies were identified. The details on load forecast methodology is attached as **Annexure-3.**

5.4 Distribution System Planning

Necessary deterministic and probable distribution system planning methods are proposed to address the system gaps focusing on reduction of losses, improving the reliability and power quality. Accordingly, any contingency plans, up gradation and reinforcement plans are proposed along with the investment plans incorporating best fit technology.

5.5 Investment Plan

The approved investment plans (from 2020 to 2023) have been validated based on the outcome of the system studies and accordingly, the yearly investment plans are outlined as per the priority matrix as detailed in **Section 9.**

6. Existing Electricity Distribution Network

6.1 Overview of the Power Supply Sources

The power supply to ten (10) Gewogs and the towns of Paro Dzongkhag is fed from 66/33kV Olathang, 33/11kV substations of Tshongdue, Shaba, Jangsa, Drukgyel and Jitsiphu substations. Further, with the completion of Pangbesa project, 66/33kV substation will be also an additional source for Paro Dzongkhag. The basic electricity distribution network model as seen from the source is predominantly radial as shown in **Figure 2.**

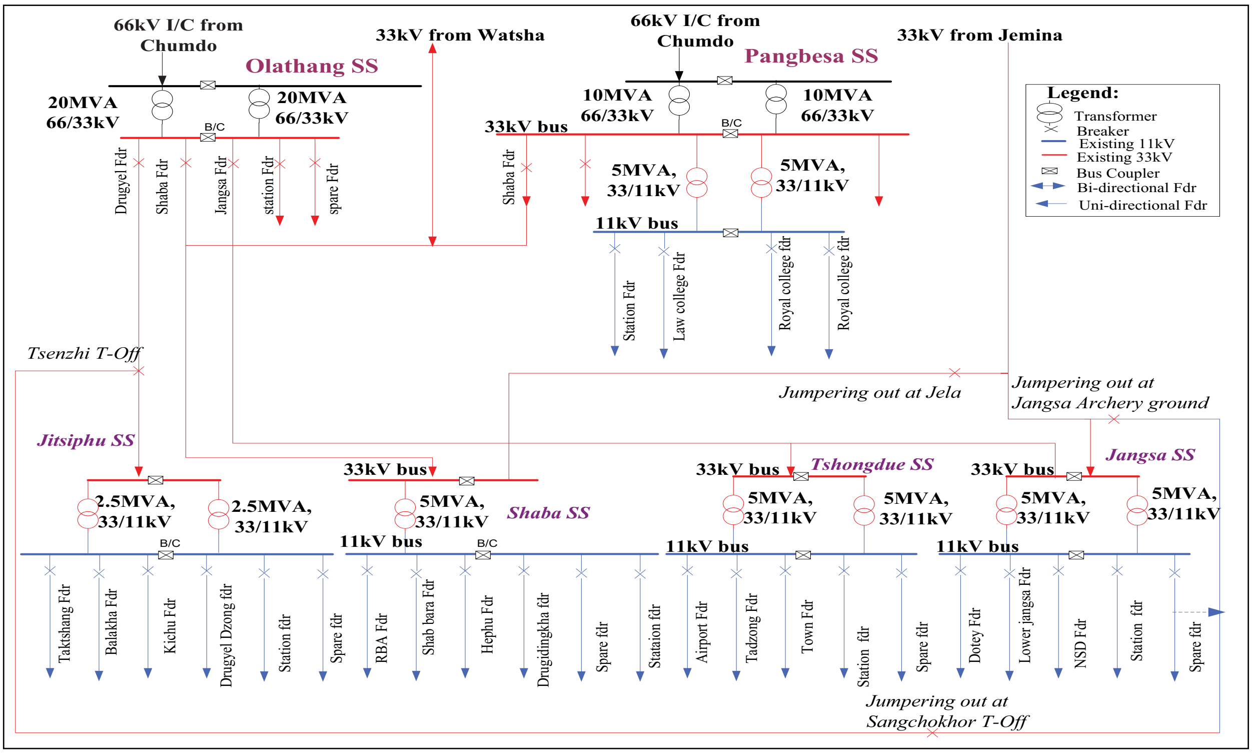


Figure 2: Electricity Distribution Schematic Diagram of Paro Dzongkhag

The Olathang substation has 66/33kV, 2x20 MVA transformers which is the primary source of power supply for Paro Dzongkhag with alternative sources from Watsa and Jemina 33kV feeders. With the completion of Pangbesa project, additional 66/33kV, 2X10MVA substation will be added to the system. As shown in the figure there are four 33/11kV substations installed in various locations with twenty-three feeders (for HV, MV and domestic customers) operated and maintained by ESD, Paro including the station feeders.

6.2 Electricity Distribution Lines

The quantity of MV and LV lines operated and maintained by ESD, Paro is summarized in **Table 1**.

Table 1: MV and LV Line Details

Sl. No.	33 kV		11 kV		Total MV line				LV lines		Total line length (km)
	OH	UG	OH	UG	OH	UG	AAAC	HV ABC	OH	UG	
1	216.01	1.52	140.22	8.57	354.23	10.09	6.37	6.75	441.690	21.50	842.63

The total MV line length is 379.44 km and the total LV line length is 463.19km. The ratio of LV to MV line length is 1.22 which reflects a high proportion of power distribution through LV networks. While the ratio of LV to MV line length would vary according to the site conditions, as a general thumb rule, network ratio of 1.2:1 (LV to MV) should be maintained for optimum initial capex and the running and maintenance costs. MV distribution network is through 33 kV and 11 kV overhead lines with some network in the town areas being through underground cables.

6.3 Distribution Transformers

The number of distribution transformers at various kVA rating levels operated and maintained by the Division is tabulated in **Table 2.**

Table 2: Total Numbers of Transformers, Installed Capacity & Customers

Sl.No.	Name of Feeder	Voltage Ratio	Number of Transformers	Installed capacity (kVA)	Total customers
1	33kV Shaba Feeder (Pangbesa)	33/0.415kV	44	5601	1325
2	33kV Shaba Feeder (Olathang)	33/0.415kV	2	375	
3	11kV RBA Feeder	11/0.230kV	3	51	1169
		11/0.415kV	10	3101	
4	11kV Shabara	11/0.240kV	3	288	96
5	11kV Hephu	11/0.240kV	1	10	497
		11/0.415kV	12	1453	
6	11kV Drugidingkha	11/0.415kV	23	5010	1791
7	11kV Shaba Station Feeder	11/0.415kV	1	200	
8	33kV Drugyel Feeder	11/0.240kV	31	415	1648
		33/0.415kV	25	2524	
9	11kV Balakha Feeder	11/0.415kV	5	1753	506
10	11kV Taktsang Feeder	11/0.415kV	5	929	30
11	11kV Drugyel Dzong	11/0.415kV	1	750	47
12	11kV Kichu Feeder	11/0.415kV	17	5135	1657
13	11kV Jitsiphu	11/0.415kV	1	200	3
14	33kV Jemina Feeder	33/0.415kV	2	126	2
15	11kV Dotey Feeder	11/0.240kV	5	83	1646
		11/0.415kV	19	1985	
16	11kV Lower Jangsa Feeder	11/0.415kV	11	3113	1515
17	11kV NSD Feeder	11/0.415kV	2	2000	1
18	11kV Tshendona	11/0.415kV	9	2413	
	11kV Jangsa Station Feeder	11/0.415kV	1	63	
19	11kV Ta Dzong	11/0.415kV	13	4345	
19	11kV Town Feeder	11/0.415kV	16	5692	1209
20	11kV Air Port	11/0.415kV	18	9365	
21	11kV Tshongdu	11/0.415kV	1	500	1
22	11kV Pangbesa Feeder	11/0.415kV	4	2510	1
23	11kV Pangbesa Feeder	11/0.415kV	3	2500	
	Total		**288**	**62,490.00**	**13,144.00**

As of June 2019, there were 288 (247 BPC & 41 Private) transformers with a total installed capacity of 62,490.00 kVA. As evident from **Table 2,** the installed capacity of transformer per customer is 4.75kVA as of June 2019. The installed transformers are generally large in capacity and few in number rather than generally small in capacity and more in numbers. The 33kV Drugyel feeder which is extended till Lingzhi Dungkhag under Thimphu Dzongkhag has 50 DTs connected to Drugyel feeder and therefore, the system study of Paro is inclusive of all the DTs of Lingzhi Dungkhag.

7. Analysis of Existing System

Based on the model developed in ETAP for the existing feeder wise distribution network, analysis of the system was carried out by considering the forecasted load growth from 2020-2030. The quality of power, reliability and energy loss of the existing network were assessed and accordingly the augmentation and reinforcement works are proposed which shall be the integral part of the investment plan. The assessment of MV lines, DTs, power sources, reliability of the power supply and energy & power consumption pattern are presented from **Section 7.1** through **Section 7.4**.

7.1 Assessment of Power Sources

The assessments of the capabilities of the power sources were exclusively done based on the existing (as on 2019) and forecasted load. The source capability assessment had to be carried out to ascertain the adequacy of the installed capacity against the existing load and the forecasted load. The source capability assessment had been carried out bifurcating HV and MV substations as detailed below.

7.1.1 HV Substation

The total installed capacity of 66/33kV Olathang substation is 40MVA (34MW @ 0.85pf) and the total FWPL as of 2019 is 20.45 MW which works out to be 60% of the available capacity at source being utilized as on 2019. The time series forecast suggests that the capacity of the existing Olathang substation would be adequate till 2030 as it is forecasted to reach 31.89MW. Similarly, the 66/33kV Pangbesa substation would be adequate to cater the forecasted load. The gap analysis on the installed capacity versus the forecasted load is attached as tabulated as **Table 3**.

Table 3: HV Power Sources

Sl.No.	Name of Source	Installed Capacity		Feeder Load 9MW)		
		MVA	**MW***	**2019**	**2025**	**2030**
1	66/33kV Olathang Substation	40	34	20.45	26.77	31.89
2	66/33/11kV Pangbesa Substation	20	17	4.46	5.42	6.34
3	66/33kV Jemina Substation**	10	8.5	0.05	0.05	0.05
	Total	**70**	**59.50**	**24.96**	**32.23**	**38.27**

**pf of 0.85 is considered for study purpose only.*

*** Only two transformers of Paro are connected to 33kV outgoing feeder. This substation is meant for the customers of Thimphu and the outgoing 33kV feeder is for contingency arrangement for customers under Paro Dzongkhag.*

7.1.2 MV Substation

As can inferred from **Table 4,** due to unbalanced load distribution, some of the 33/11kV substations might get overloaded and the assessment of power requirement against the installed capacity of each of the substations is presented as follows.

Table 4: MV Power Sources

Sl. No.	Name of Substation	Source Capacity		Feeder Load (MW)		
		MVA	**MW**	**2019**	**2025**	**2030**
1	33/11 KV Jangsa Substation	10	8.5	4.03	5.64	6.37
2	33/11kV Jitsiphu Substation	5	4.25	2.96	3.93	4.74
3	33/11kV Shaba Substation	5	4.25	4.07	5.39	6.50
4	33/11kV Tshongdue Substation	10	8.5	8.32	10.44	12.51
	Total	**30**	**25.50**	**19.38**	**25.40**	**30.12**

a) 33/11kV, 2x5MVA Jangsa Substation

The 33/11kV Jangsa substation has recorded FWPL of 4.03MW as on 2019 against the installed capacity of 8.5MW and is expected to reach 5.64MW & 6.37MW by 2025 & 2030 respectively. Therefore, as per the forecasted load against the installed capacity, the Jangsa substation would be adequate to meet the forecasted load requirement.

b) 33/11kV, 2x2.5MVA Jitsiphu Substation

The 33/11kV Jitsiphu substation has recorded FWPL of 2.96MW as on 2019 and is expected to reach 3.93MW & 4.74MW by 2025 & 2030 respectively against the installed capacity of 4.25MW. As per the forecasted load against the installed capacity, the Jitsiphu substation would be adequate to meet the forecasted load requirement. However, as the Paro development has been overwhelmed by the “Paro Valley Plan” concept, the power requirement from Jitsiphu substation is expected to be more than is forecasted. Therefore, it is proposed to up-grade the capacity to 7.5MVA.

c) 33/11kV, 1x5 Shaba Substation

The 33/11kV Shaba substation has recorded FWPL of 4.07MW as on 2019 against the installed and is expected to reach 5.39MW & 6.50MW by 2025 & 2030 respectively. Therefore, as per the forecasted load against the installed capacity, the Shaba substation would not be adequate to meet the forecasted load. Therefore, it would be prudent to upgrade the capacity to 10MVA by 2025 which shall also serve as contingency plan.

d) 33/11kV, 2x5MVA Tshongdue Substation

The 33/11kV Tshongdue substation has recorded FWPL of 8.32MW as on 2019 and is expected to reach 10.44MW & 12.51MW by 2025 & 2030 respectively against the installed capacity of 8.50MW. Therefore, as per the forecasted load against the installed capacity, the Tshogndue substation would not be adequate to meet the forecasted load requirement. Due to space constraint in the existing Tshongdue substation, in lieu of proposing to add 5MVA transformer, it would be prudent to propose 10MVA transformer and use the existing 5MVA for Jitsiphu substation. This arrangement would maximize the optimum usage of the existing distribution infrastructure.

Therefore, to meet the increasing power demand as forecasted, it is proposed to up-grade the substation capacities as detailed in the foregoing section.

7.2 Assessment of MV Feeders

Feeder wise planning is necessary to ensure that the power delivery capacity, power quality and reliability requirements of the customers are met. In distribution system, capacity assessment of existing MV feeders is important to ensure that feeders are adequate to transmit the peak demand of the load connected to the feeders. Particularly, the capacity assessment of the feeders enables identification of feeders that require reinforcement and reconfiguration works.

The behavior of the MV feeders are assessed based on the existing and forecasted load, feeder wise energy loss, reliability, and single to three-phase line conversions which are outlined vividly in **Section 7.2.1** through **Section 7.2.4**. Further, recognizing that the asset life of the distribution system is thirty years (30), our system should be able to handle the load growth (peak demand) for next 30 years. Therefore, it is equally important to consider the asset life of the system in addition to the assessment of the system in different time horizons.

7.2.1 Assessment of MV Feeder with Load

The feeder wise peak power consumption was compiled based on the historical data. The array of daily and monthly peak demand was sorted to obtain the annual peak demand. The feeder-wise peak demand recorded at the source is presented in **Table 5** and the corresponding feeder-wise annual load curve is presented in **Figure 3.**

Table 5: Feeder Wise Peak Power Demand (2019-2030)

Sl. No.	Feeder Name	Feeder Load (MW)		
		2019	2025	2030
1	33kV Drukgyal Feeder	3.94	5.21	6.42
2	33kV Shaba Feeder	4.16	5.48	6.59
3	33kV Jangsa Feeder	12.35	16.08	18.88
4	33kV Wanakha/Dawakha Feeder	Alternative route		
5	33KV Jemina Feeder	0.05	0.05	0.05

Sl. No.	Feeder Name	Feeder Load (MW)		
		2019	2025	2030
6	33kV Shaba Feeder from Jangsa	1.91	2.44	2.93
7	11kV Royal Academy Feeder	2.56	2.98	3.41
	Total load (MW)	**24.96**	**32.23**	**38.27**

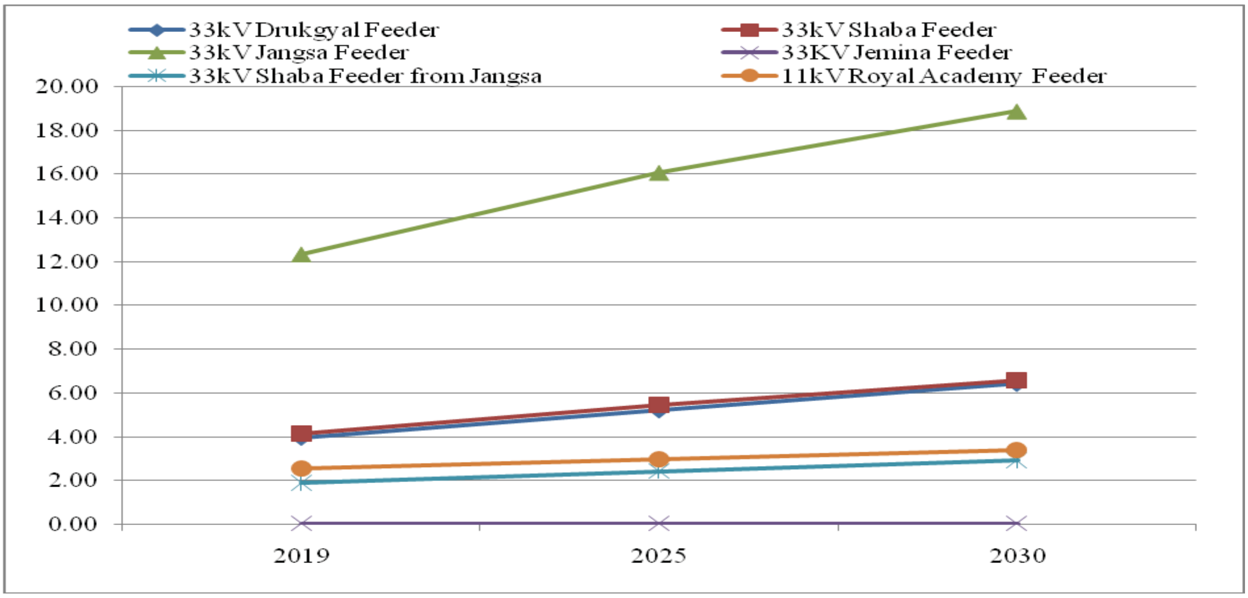


Figure 3: Plot of Feeder Wise Forecasted load of ESD, Paro

The assessment of the feeder is carried out based on the following aspects:

a) System study: Existing load

b) System study based on forecasted load: 2025 & 2030 scenario

a) System Study (Existing Load)

Based on the peak load (2019) and the thermal capacity of the line, the load flow and accordingly the assessment of the feeder was carried out. The simulation result shows no abnormality and the ampacity capability of the feeders will be within the range with the existing load. The thermal capacity of the different conductor sizes is as shown in **Table 6.**

Table 6: Thermal loading of ACSR conductor at different voltage levels

Sl. No.	ACSR Conductor Type	Ampacity of Conductor	MVA rating corresponding to the Ampacity
33 kV Voltage Level			
1	RABBIT	193	11.031
2	DOG	300	17.146
3	WOLF	398	22.748
11 kV Voltage Level			
1	RABBIT	193	3.677
2	DOG	300	5.715
3	WOLF	398	7.582

Ampacity (thermal loading) of the lines have been calculated based on IS 398 (Part-II): 1996 for maximum conductor temperature 85°C for ACSR conductors considering an ambient temperature of 40°C.

The ampacity of all the 33kV (all the lines constructed on wolf and some on Dog) and 11kV feeders would be within the range with the existing load however, the 11kV Airport and 11kV Town feeders constructed on Dog and Rabbit would exceed the thermal limit of the conductors as it is forecasted to reach around 4MW and 5MW by 2025 and 2030 respectively. Due to shorter circuit line length, voltage profile is expected to be within the permissible range. Similarly, as the Dzongkhag is situated in the alpine region and the peak power requirement occurring in winter months, the thermal loading capacity would be enhanced due to natural phenomenon. However, degree of the feeder loading has to be closely monitored as the accuracy of the forecasted load would deviate more in the distant future.

b) System Study with Forecasted Load (2025 and 2030)

The peak power demand from 2014-2019 has been considered to forecast the peak power demand for the next 10 years (2020-2030) as shown in **Table 7** adopting the commonly practiced methodology of LRM and TSA with the help of ETAP. The detailed load simulation result is attached as **Annexure-4.**

Table 7: Feeder Peak Power Demand Forecast

Sl. No.	Feeder Name	Circuit Length (km)	Total Transformer	Installed Capacity (kVA)	Feeder Load (MW)		
					2019	2020	2030
1	11kV Dotey Feeder	29.38	24	2068	0.77	0.94	1.12
2	11kV Lower Jangsa Feeder	7.71	11	3,113.00	1.16	1.50	1.82
3	11kV NSD Feeder	0.47	2	2,000.00	0.79	1.53	1.53
4	11kV Tshendona Feeder	9.99	9	2,413.00	1.28	1.64	1.86
5	11kV Jangsa Station Feeder	0.04	1	63.00	0.03	0.03	0.03
6	11kV Balakha Feeder	2.84	5	1,753.00	0.65	0.71	0.82
7	11kV Taktshang Feeder	5.93	5	929.00	0.27	0.48	0.69
8	11kV Kichu Feeder	9.64	17	5,135.00	1.94	2.49	2.98
9	11kV Drugyel Dzong Feeder	3.92	1	750.00	0.05	0.21	0.21
10	11kV Jitsiphu Station Feeder	0.04	1	200.00	0.03	0.03	0.03
11	11kV RBA Feeder	14.45	13	3,152.00	1.39	1.84	2.20
12	11kv Shabbara Feeder	3.14	3	288.00	0.21	0.22	0.22
13	11kV Hephu Feeder	18.34	13	1,463.00	0.44	0.48	0.51
14	11kV Drugidingkha Feeder	17.56	23	5,010.00	1.99	2.82	3.53
15	11kV Shaba station feeder	0.04	1	200.00	0.03	0.03	0.03
16	11kV Airport Feeder	9.22	18	9,365.00	3.29	4.34	5.25
17	11kV Ta-Dzong Feeder	9.68	13	4,345.00	1.79	1.98	2.19
18	11kV Town Feeder	11.17	16	5,692.00	2.99	3.86	4.81
19	11kV Tshongdue Station Feeder	0.04	1	500.00	0.26	0.26	0.26
20	11kV Dzong Feeder	1.33	4	2,510.00	1.28	1.49	1.71
21	11kV School Feeder.	1.85	3	2,500.00	1.28	1.49	1.70
22	33kV Jemina Station Feeder	9.47			0.05	0.05	0.05
23	33kV Drugyel Feeder (O/G)	127.17	56	2,939.00	0.99	1.28	1.68
24	33kV Shaba Feeder from Jangsa (Pangbesa)	10.73	44	5,939.00	1.91	2.44	2.93
25	33kV Shaba Feeder from Olathang	53.46	2	0.00	0.09	0.09	0.09
26	33kV Jemina-Jangsa Feeder	15.27	2	126.00			
27	33kV Olathang to Tsongdue and to Jangsa Feeder	4.51	These are the trunk lines and there are no transformers connected in these sections of lines.				
28	33kV Jangsa-Drugyel Feeder	5.44					
29	33kV Olathang Station Feeder	0.05					

Sl. No.	Feeder Name	Circuit Length (km)	Total Transformer	Installed Capacity (kVA)	Feeder Load (MW)		
					2019	2020	2030
	Overall total	**377.44**	**288.00**	**62,490.00**	**24.96**	**32.23**	**38.27**

From the above table, it is observed that the highest peak load as on 2019 is 4.16MW for 33kV Shaba feeder which is expected to reach up to 5.48MW and 6.59MW by 2025 and 2030 respectively.

Although it is conclusive that the existing MV lines are adequate to evacuate the power if assessed independently, the voltage profile would go below the standard accepted range of (±) 10% should the existing network supply the forecasted load as tabulated in **Table 8.** The load carrying capacity of a feeder is determined by the line length and degree of load connected in addition to other parameters (e.g., ampacity).

Table 8: Feeders with Poor Voltage Profile (2019, 2025 and 2030)

Sl. No.	Name of Feeder	Circuit Length (km)	End Voltage (kV)	% Variation	Load (MW)			Remarks
					2019	2025	2030	
A	**2019**							
1	11kV Kichu Feeder	9.64	9.13	83.02	1.94	2.50	2.98	
2	11kV RBA Feeder	14.45	9.62	87.42	1.39	1.84	2.20	
3	11kV Dotey Feeder	29.38	9.89	89.89	0.77	0.94	1.12	
4	11kV Lower Jangsa	7.71	9.62	87.49	1.16	1.50	1.82	
5	11kV Ta-Dzong	9.68	9.71	88.23	1.79	1.98	2.19	
6	11kV Tshendona	9.99	9.55	86.86	1.28	1.64	1.87	
7	11kV Drugidingkha	17.56	8.15	74.13	1.99	2.82	3.53	With increased source capacity
8	11kV Taktshang Feeder	5.93	10.10	91.80	0.27	0.48	0.70	
9	11kV Town Feeder	11.17	9.71	88.24	2.99	3.86	4.81	
B	**2025**							

Sl. No .	Name of Feeder	Circuit Length (km)	End Voltage (kV)	% Variation	Load (MW)			Remarks
					2019	2025	2030	
1	11kV Kichu Feeder	9.64	9.17	83.38	1.94	2.49	2.98	Rabbit to Dog converted (4.6km)
2	11kV RBA Feeder	14.45	9.62	87.42	1.39	1.84	2.2	Rabbit to Wolf converted (14.45km)
3	11kV Dotey Feeder	29.38	9.50	86.37	0.77	0.94	1.12	
4	11kV Lower Jangsa	7.71	9.19	83.59	1.16	1.5	1.82	
5	11kV Ta-Dzong	9.68	9.33	84.83	1.79	1.98	2.19	
6	11kV Tshendona	9.99	9.07	82.49	1.28	1.64	1.86	
7	11kV Drugidingkha	17.56	7.92	72.00	1.99	2.82	3.53	With increased source capacity
8	11kV Taktshang Feeder	5.93	9.80	89.13	0.27	0.48	0.69	
9	11kV Town Feeder	11.17	9.34	84.9	2.99	3.86	4.81	
C	**2030**							
1	11kV Kichu Feeder	9.64	8.81	80.11	1.94	2.49	2.98	Rabbit to Dog converted (4.6km)
2	11kV RBA Feeder	14.45	9.29	84.42	1.39	1.84	2.2	Rabbit to Wolf converted (14.45km)
3	11kV Dotey Feeder	29.38	9.27	84.31	0.77	0.94	1.12	
4	11kV Lower Jangsa	7.71	8.90	80.9	1.16	1.5	1.82	
5	11kV Ta-Dzong	9.68	9.12	82.89	1.79	1.98	2.19	
6	11kV Tshendona	9.99	8.76	79.66	1.28	1.64	1.86	
7	11kV Drugidingkha	17.56	7.70	70.00	1.99	2.82	3.53	With increased source capacity
8	11kV Taktshang Feeder	5.93	9.55	86.8	0.27	0.48	0.69	
9	11kV Town Feeder	11.17	9.05	82.31	2.99	3.86	4.81	

The 11kV feeders which are reflected in the table above would violate the voltage profile with the current loading (as of 2019) and the forecasted load as well which are detailed as follows:

a) 11kV Kichu Feeder

The Kichu feeder has 9.64km constructed on Dog (2.68km), Rabbit (4.6km) and HV ABC conductors. Most of the loads connected to this feeder are rural customer and therefore, the connected loads are static/impedance load (90%) in nature. The voltage profile at the end of the feeder is 83.02% with the existing load and would decrease with the increased forecasted load. Simulation result shows that it will be 83.38% and 80.11% by (with re-sizing of the conductor from Rabbit to Dog- 4.6km) 2025 and 2030 with the forecasted load. With the proposed resizing of section of line from Rabbit to Wolf and making use of the tap of power transformer, the simulation result shows that the voltage profile would be increased to 90.56%. Therefore, with ±5 provision available at DT, the voltage profile would be within the permissible range with the forecasted load. However, proposal to re-size the conductor would mean that BPC has to take shutdowns which will not only pose inconveniences both to BPC and to the customers; it would also block the revenue generation. Therefore, it will be prudent for BPC to propose other technologies just for improving the voltage profile prior to proposing the re-sizing of the conductor.

b) 11kV RBA Feeder

The RBA feeder has 14.45km constructed on Rabbit conductor. Most of the loads connected to this feeder are rural customer and therefore, the connected loads are static/impedance load (90%) in nature. The voltage profile at the end of the feeder is 84.42% with the existing load and would decrease with the forecasted load. Simulation result shows that it will be 87.42% and 84.42% (converted to Wolf) in 2025 and 2030 forecasted load respectively. It is prudent to improve the voltage profile by making use of the incremental tap changes prior to resorting to other alternatives. Therefore, with proposed up-grading of the 33/11kV, 1X5MV to 10MVA Shaba substation along with the tap changer and assuming that ±5% provision is also available at DT level, the existing conductor size would be adequate to cater the load. However, it is strongly recommended to closely monitor the loading pattern post 2025.

c) 11kV Dotay Feeder

The Dotay feeder has 29.38km constructed on Dog (7.16) and Rabbit (22.22km) conductors. Most of the loads connected to this feeder are rural customer and therefore, the connected loads are static/impedance load (90%) in nature. The voltage profile at the end of the feeder is 89.89% with the existing load and would decrease with the increased forecasted load. Simulation result shows that it will be 86.37% and 84.31% in 2025 and 2030 forecasted load respectively. It is prudent to improve the voltage profile by making use of the incremental tap changes prior to resorting to other alternatives. Making use of the tape of power transformer would improve the voltage profile to 90.62 even with the 2030 proposed forecasted load. Therefore, the 11kV Dotey feeder would be adequate to cater the load till 2030.

d) 11kV Lower Jangsa Feeder

The Lower Jangsa feeder has 7.71km constructed on Dog (1.2), Rabbit (2.9km) and HV ABC (3.48km) conductors. Most of the loads connected to this feeder are rural customer and therefore, the connected loads are static/impedance load (90%) in nature. The voltage profile at the end of the feeder is 87.49% with the existing load and would decrease with the increased forecasted load. Simulation result shows that it will be 83.59% and 80.90% in 2025 and 2030 forecasted load respectively. It is prudent to improve the voltage profile by making use of the incremental tap changes prior to resorting to other alternatives. Making use of the tape change of the power transformer would improve the voltage profile to 94.36%, 90.09% and 86.94% in 2019, 2025 & 2030's forecasted load respectively. Further, with the ±5 provision at the DT, the voltage profile would be within the permissible range for the customers connected to this feeder.

e) 11kV Ta-Dzong Feeder

The Ta-Dzong feeder has 9.68km constructed on Dog (3.83) and Rabbit (5.18km) conductors. Most of the loads connected to this feeder are rural customer and therefore, the connected loads are static/impedance load (90%) in nature. The voltage profile at the end of the feeder is 88.23% with the existing load and would decrease with the increased forecasted load. Simulation result shows that it will be 84.83% and 82.89% in 2025 and 2030 forecasted load respectively. It is prudent to improve the voltage profile by making use of the incremental tap changes prior to resorting to other alternatives. Making use of the tape change of the power transformer would improve the voltage profile to 90.50% and 88.83% in 2025 & 2030's forecasted load respectively. Further, with the ±5 provision available at the DT, the voltage profile would be within the permissible range for the customers connected to this feeder.

f) 11kV Tshendona Feeder

The Tshendona feeder has 9.68km constructed on Wolf (4.11) and Rabbit (5.76km) conductors. Most of the loads connected to this feeder are rural customer and therefore, the connected loads are static/impedance load (95%) in nature. The voltage profile at the end of the feeder is 86.86% with the existing load and would decrease with the increased forecasted load. Simulation result shows that it will be 82.49% and 79.66% in 2025 and 2030 forecasted load respectively. It is prudent to improve the voltage profile by making use of the incremental tap changes prior to resorting to other alternatives. Making use of the tape change of the power transformer would improve the voltage profile to 93.79%, 89.11% and 86.07% in 2019, 2025 & 2030's forecasted load respectively. Further, with the ±5 provision available at the DT, the voltage profile would be within the permissible range for the customers connected to this feeder.

g) 11kV Drugidingkha Feeder

The Drugidingkha feeder has 17.56km constructed on Dog (3.7) and Rabbit (13.24km) conductors. Most of the loads connected to this feeder are rural customer and therefore, the connected loads are static/impedance load (90%) in nature. The voltage profile at the end of the feeder will be less than 74.13% as simulation result shows that the voltage profile would be 74.13% with up-graded Shaba substation (5MVA to 10MVA). With the re-sizing of conductor to Wolf with tap provision being used would improve the voltage profile up to 89.33%. The simulation result shows that with re-sized conductor to wolf with tap utilized, the voltage profile would be 90.60% and 89.33% in 2025 and 2030 respectively. Therefore, it is proposed to re-size the conductor to Wolf. However, proposal to re-size the conductor would mean that BPC has to take shutdowns which will not only pose inconveniences both to BPC and to the customers; it would also block the revenue generation. Therefore, it will be prudent for BPC to propose other technologies just for improving the voltage profile prior to proposing the re-sizing of the conductor.

h) 11kV Taktshang Feeder

The Taktshang feeder has 5.93km constructed on Rabbit (5.57) and UG (0.18km) conductors. Most of the loads connected to this feeder are rural customer and therefore, the connected loads are static/impedance load (90%) in nature. The voltage profile at the end of the feeder is 91.80% with the existing load and would decrease with the increased forecasted load. Simulation result shows that it will be 89.13% and 86.80% in 2025 and 2030 forecasted load respectively. It is prudent to improve the voltage profile by making use of the incremental tap changes prior to resorting to other alternatives. Making use of the tape change of the power transformer and ±5 provision available at the DT, the voltage profile would be within the permissible range for the customers connected to this feeder.

i) 11kV Town Feeder

The Town feeder has 11.17km constructed on UG, Dog, Rabbit (8.86) and HV ABC conductors. Most of the loads connected to this feeder are rural customer and therefore, the connected loads are static/impedance load (90%) in nature. The voltage profile at the end of the feeder is 88.24% with the existing load and would decrease with the increased forecasted load. Simulation result shows that it will be 84.90% and 82.31% in 2025 and 2030 forecasted load respectively. With the proposal to up-grade the Tshongdue substation from 10MVA to 15 MVA in 2025 and making use of the tap changer of power transformer, the voltage profile would improve to 90.32% and 87.83% in 2025 & 2030 forecasted load respectively. Further with an available provision of ±5 at DT level, the voltage profile would be within the permissible range for the customers connected to this feeder.

The voltage profile can be improved either by up-grading the source (if at all required), utilizing the tap-increment in power transformer as well the DT, reconfiguring the feeder or by re-sizing the conductor. Incorporating all the available options, it was observed that only the 11kV Drugidingkha and Kichu feeders would continue experiencing the voltage regulation due to longer circuit line length and degree of load connected to this feeder. Therefore, the voltage profile of the feeder can be achieved either by constructing new substation, re-sizing the conductor or by exploring the best fit technology (e.g. installing AVR/voltage boosters) in these feeders. **Table 9** shows the improvement in the voltage profile by incorporating the reconfiguration of lines and sources, incorporating the available alternatives and by proposing technology in the system.

Table 9: Feeder Wise Voltage Improvement

Sl. No.	Name of Feeder	Before		After		Remarks
		Voltage (kV)	% Variation	Voltage (kV)	% Variation	
A	**2019**					
1	11kV Kichu Feeder	9.13	83.02	10.48	95.28	Tap utilized
2	11kV RBA Feeder	9.62	87.42	10.07	91.52	Up-graded source and tap utilized
3	11kV Dotey Feeder	9.89	89.89	10.65	96.81	Tap utilized
4	11kV Lower Jangsa	9.62	87.49	10.38	94.36	
5	11kV Ta-Dzong	9.71	88.23	-		
6	11kV Tshendona	9.55	86.86	10.32	93.79	Tap utilized
7	11kV Drugidingkha	8.15	74.13	10.20	92.77	With increased source capacity & Tap utilized
8	11kV Taktshang Feeder	10.10	91.80	-		
9	11kV Town Feeder	9.71	88.24	-		
B	**2025**					
1	11kV Kichu Feeder	9.17	83.38	10.09	91.71	Rabbit to Wolf converted (4.6km) & Tap utilized
2	11kV RBA Feeder	9.62	87.42	9.66	87.78	Up-graded source and tap utilized
3	11kV Dotey Feeder	9.50	86.37	10.21	92.85	Tap utilized
4	11kV Lower Jangsa	9.19	83.59	9.91	90.09	Tap utilized
5	11kV Ta-Dzong	9.33	84.83	9.96	90.50	Tap utilized
6	11kV Tshendona	9.07	82.49	9.80	89.11	Tap utilized
7	11kV Drugidingkha	7.92	72.00	9.97	90.60	With increased source capacity & Tap utilized
8	11kV Taktshang Feeder	9.80	89.13	9.83	89.36	Tap utilized
9	11kV Town Feeder	9.34	84.9	9.94	90.32	Up-graded source and tap utilized

Sl. No.	Name of Feeder	Before		After		Remarks
		Voltage (kV)	% Variation	Voltage (kV)	% Variation	
C	**2030**					
1	11kV Kichu Feeder	8.81	80.11	9.96	90.56	Rabbit to Wolf converted (4.6km) & Tap utilized
2	11kV RBA Feeder	9.29	84.42	9.29	84.42	Up-graded source and tap utilized
3	11kV Dotey Feeder	9.27	84.31	9.97	90.62	Tap utilized
4	11kV Lower Jangsa	8.90	80.9	9.56	86.94	Tap utilized
5	11kV Ta-Dzong	9.12	82.89	9.77	88.83	Tap utilized
6	11kV Tshendona	8.76	79.66	9.47	86.07	Tap utilized
7	11kV Drugidingkha	7.70	70.00	9.83	89.33	With increased source capacity & Tap utilized
8	11kV Taktshang Feeder	9.55	86.8	9.58	87.07	Tap utilized
9	11kV Town Feeder	9.05	82.31	9.66	87.83	Up-graded source and tap utilized

7.2.2 Energy Loss Assessment of the MV Feeders

Energy losses in the distribution network are inherent as the power transmission and distribution system are associated with the transformers and lines. However, it is crucial to maintain the energy loss at an optimal level by engaging in timely improvement of the distribution infrastructures and not reacting to the localized system deficiencies. The objective of the energy loss assessment is to single out the feeder (s) with maximum loss (es) and put in additional corrective measures to minimize to the acceptable range.

To carry out the assessment, the energy sales, purchase and loss is as tabulated in **Table 10** and as shown in **Figure 4.**

Table 10: Summary of Total Energy Loss (MU)

Sl.No.	Particulars	2014	2015	2016	2017	2018	Average
1	Energy Requirement (MU)	42.28	45.59	48.84	53.38	60.19	50.06
2	Energy Sales in (MU)	38.85	39.88	44.15	47.40	52.33	44.52

Sl.No.	Particulars	2014	2015	2016	2017	2018	Average
3	**Total Loss (MU)**	**3.43**	**5.72**	**4.68**	**5.98**	**7.86**	5.54
	Total loss (%)	**8.12%**	**12.54%**	**9.59%**	**11.20%**	**13.06%**	**10.90%**

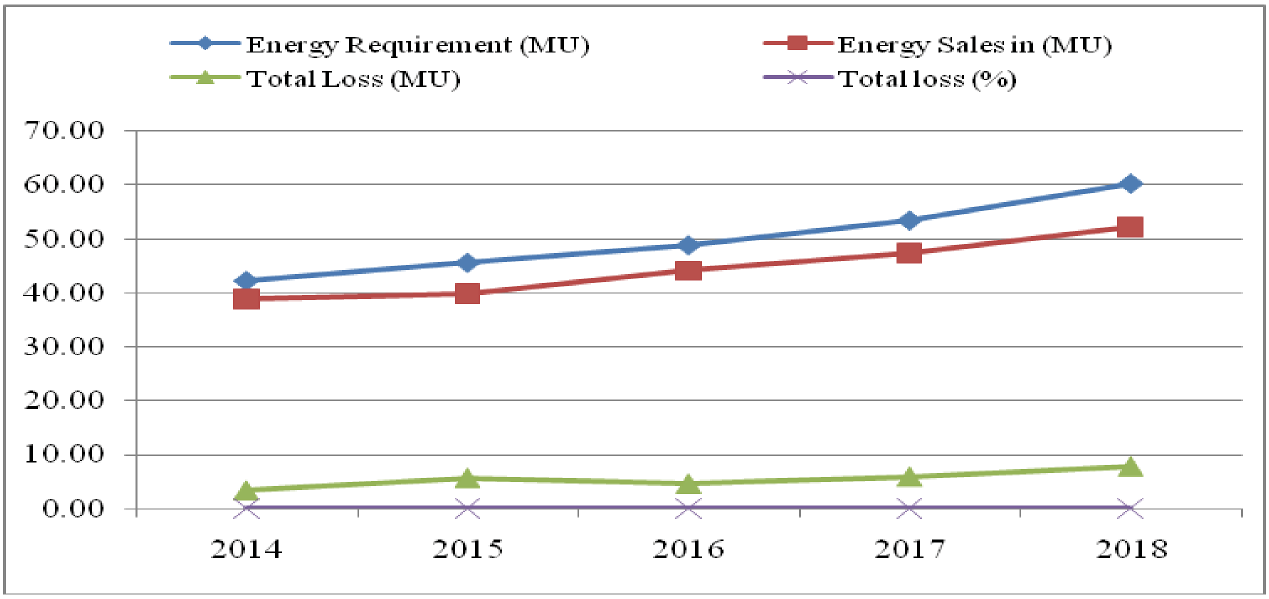


Figure 4: Plot of Total Energy Losses (MU)

Generally, the system loss (MV & LV) is 8.9% and any loss more than this for the distribution network would require in-depth study. An independent study carried out by 19 ESDs for 38 feeders in 2017 (two feeders each in ESD with more loss) showed that average of 6.84% is due to technical loss. The study also showed that loss pattern was never consistent because of variant characteristics of distribution network and loading pattern.

The average energy loss of the entire feeder 10.90% (5.54 million units on average) from 2014 to 2018 and the Dzongkhag has experienced increasing trend in loss which may be attributed to mass rural electrification works carried out from 2014-2017 (Lingzhi Dungkhag under Thimphu Dzongkhag).

As the feeder wise energy details were not available, the energy loss was redistributed to the feeders based on number of customers connected and circuit line length and accordingly the feeder wise energy loss was worked as shown in **Table 11.** It indicates that 33kV Drugyel, followed by 33kV Shaba, 11kV Dotey, 11kV Drugidingkha and 11kV Hephu feeders which generally have longer circuit length and more loads connected had contributed more loss in comparison to other feeders. Therefore, the Dzongkhag has to focus more on reducing the losses of these feeders though attempting to reduce the technical loss might inculcate high up-front cost, effort has to be put in place to reduce the commercial loss.

Table 11: Feeder Wise Energy Loss (in MU)

Sl.No.	Feeder Name	Circuit Length (km)	2014	2015	2016	2017	2018	Loss %
1	11kV Dotey Feeder	29.38	0.38	0.44	0.36	0.47	0.61	7%
2	11kV Lower Jangsa Feeder	7.71	0.24	0.12	0.10	0.12	0.16	2%
3	11kV NSD Feeder	0.47	0.11	0.01	0.01	0.01	0.01	0%
4	11kV Tshendona Feeder	9.99	0.22	0.15	0.12	0.16	0.21	3%
5	11kV Jangsa Station Feeder	0.04	0.00	0.00	0.00	0.00	0.00	0%
6	11kV Balakha Feeder	2.84	0.12	0.04	0.04	0.04	0.06	1%
7	11kV Taktshang Feeder	5.93	0.10	0.09	0.07	0.09	0.12	2%
8	11kV Kichu Feeder	9.64	0.37	0.15	0.12	0.15	0.20	3%
9	11kV Drugyel Dzong Feeder	3.92	0.08	0.06	0.05	0.06	0.08	1%
10	11kV Jitsiphu Station Feeder	0.04	0.01	0.00	0.00	0.00	0.00	0%
11	11kV RBA Feeder	14.45	0.30	0.22	0.18	0.23	0.30	4%
12	11kv Shabbara Feeder	3.14	0.04	0.05	0.04	0.05	0.07	1%
13	11kV Hephu Feeder	18.34	0.25	0.28	0.23	0.29	0.38	5%
14	11kV Drugidingkha Feeder	17.56	0.43	0.27	0.22	0.28	0.37	5%
15	11kV Shaba station feeder	0.04	0.01	0.00	0.00	0.00	0.00	0%
16	11kV Airport Feeder	9.22	0.60	0.14	0.11	0.15	0.19	4%
17	11kV Ta-Dzong Feeder	9.68	0.33	0.15	0.12	0.15	0.20	3%
18	11kV Town Feeder	11.17	0.41	0.17	0.14	0.18	0.23	4%
19	11kV Tshongdue Station Feeder	0.04	0.03	0.00	0.00	0.00	0.00	0%
20	11kV Dzong Feeder	1.33	0.15	0.02	0.02	0.02	0.03	1%
21	11kV School Feeder	1.85	0.15	0.03	0.02	0.03	0.04	1%
22	33kV Jemina Station Feeder	9.47	0.09	0.14	0.12	0.15	0.20	2%
23	33kV Drugyel Feeder (O/G)	127.17	1.32	1.93	1.58	2.01	2.65	30%
24	33kV Shaba Feeder from Jangsa(Pangbesa)	10.78	0.41	0.16	0.13	0.17	0.22	4%
25	33kV Shaba Feeder from Olathang	58.18	0.55	0.88	0.72	0.92	1.21	14%
26	33kV Jemina-Jangsa Feeder	15.27	0.15	0.23	0.19	0.24	0.32	4%

Sl.No.	Feeder Name	Circuit Length (km)	2014	2015	2016	2017	2018	Loss %
	Overall total	**377.65**	**6.87**	**5.72**	**4.68**	**5.98**	**7.86**	**100%**

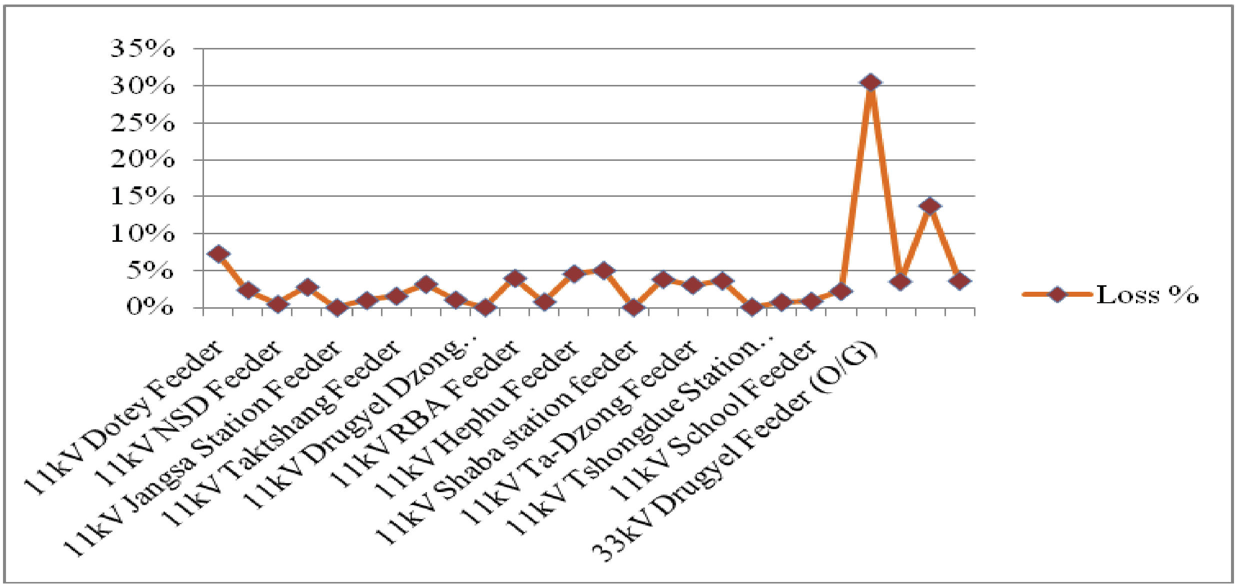


Figure 5: Feeder Wise Energy Losses (MU) of ESD, Paro

7.2.3 Reliability Assessment of the MV Feeders

Today's emphasis in the power sector has shifted to providing reliable power supply as electricity itself is positioned as one of the essential needs. However, improving reliability comes with its inherent costs as it involves embracing additional preventive and corrective measures leading to substantial up-front capital investment. Any major reliability improvement strategies need to be adopted only after carefully understanding the costs involved and the benefits that will be accrued from implementing such strategies. Failure rate, repair time and restoration time are some important parameters defining reliability. Reducing the values of one or more of the above parameters can improve reliability considerably.

In addition to ensuring that the MV feeders have the required capacity, it is also very important to ensure that the MV feeders are reliable. In order to assess the reliability of the distribution system, the historical data was referred. The yearly (2017-2019) feeder reliability indices summary is compiled as tabulated in **Table 12** and details used to derive such summary is attached as **Annexure-5**. The interruptions with less than five minutes were omitted from the computation. The actual records (both within and beyond ESDs control) were considered for actual representation to compute the reliability indices. The average reliability indices viz. SAIFI and SAIDI compiled for 2017-2019 are 17.74 and 29.33 respectively which is reasonably in the acceptable range.

Table 12: Feeder Wise Reliability Indices

Sl.No.	**Year**	**Reliability Indices**	**33kV Drugyel Feeder**	**33kV Shaba Feeder**	**33kV Jangsa Feeder**	**33kV Pangbesa Feeder***	**33kV Jemina Feeder**
1	2017	SAIFI	2.68	9.12	*	1.97	1.48
		SAIDI	8.62	13.65		1.12	0.94
2	2018	SAIFI	4.39	15.92	0.03	3.07	2.24
		SAIDI	13.16	24.34	0.67	1.92	3.72
3	2019	SAIFI	2.26	5.63		**	***
		SAIDI	6.64	8.03			
	Overall total	**SAIFI**	**3.11**	**10.22**	**0.03**	**2.52**	**1.86**
		SAIDI	**9.47**	**15.34**	**0.67**	**1.52**	**2.33**
	Average			***SAIFI***	***17.74***	***SAIDI***	***29.33***

* *There is no reliability data as the line was shut down for up-gradation works (Conversion from conventional to GIS for Olathang substation).*

*** The power was fed from Watsa substation (Watsa to Susuna and then to Paro via Dawakha line). *** The power was fed from 33kV Jangsa Feeder.*

The above summary (compiled from 2017-2019) indicates that the 33kV Drugyel and 33kV Shaba feeders have sustained more interruptions compared to the other feeders. Assessment on each of the feeders along with the proposed solution is detailed as follows. It is found that most of the interruptions are due to maintenance works (30%), transient faults (over current & earth faults-28%) and jumpering (23%). Some of the terminations in the interconnections are made through jumpering unlike other smarter switches which would be advisable to install better equipment so that making and breaking down time for the line can be reduced, safer to operate and would also maximize the revenue generation.

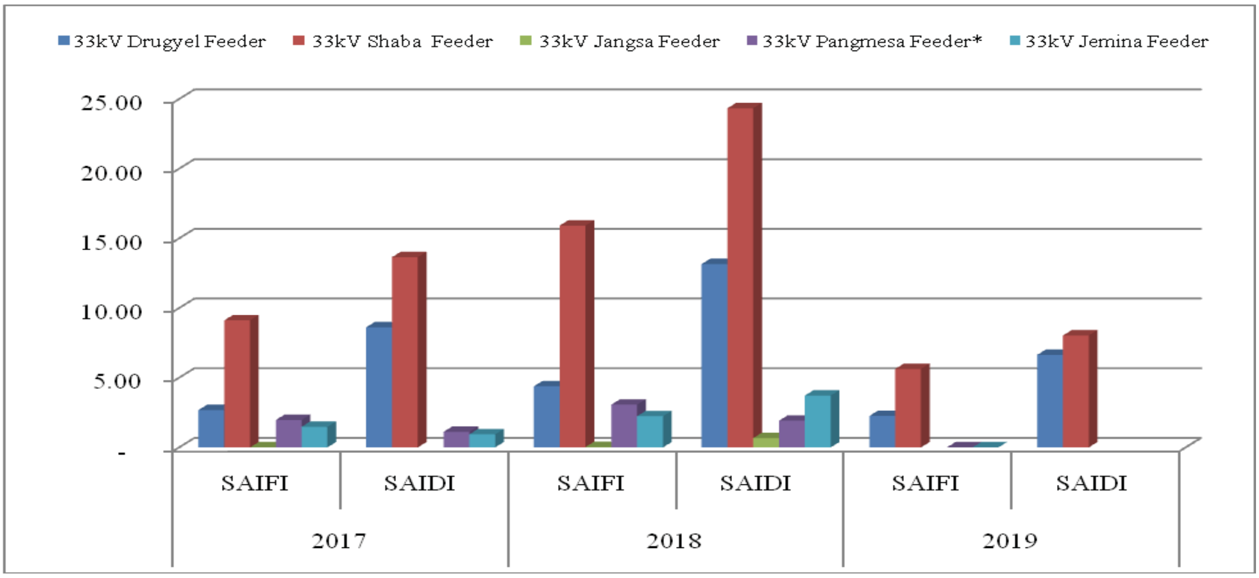
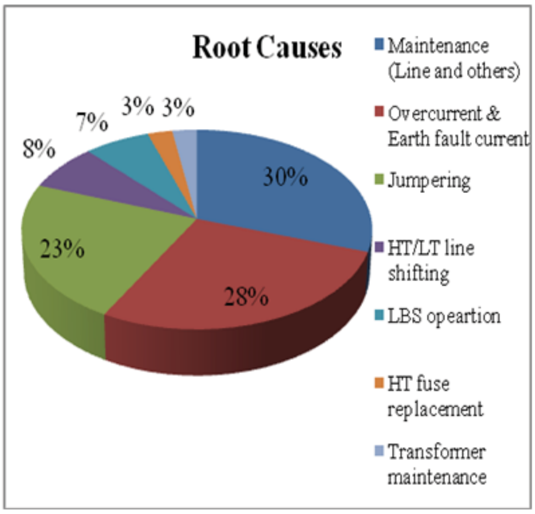


Figure 6: Feeder Wise Reliability Indices of ESD, Paro



Root Causes	Frequency	% Distribution
Maintenance (Line and others)	36	30%
Over current & Earth fault current	33	28%
Jumpering	27	23%
HT/LT line shifting	9	8%
LBS operation	8	7%
HT fuse replacement	3	3%
Transformer maintenance	3	3%
Total	**119**	**100%**

Figure 7: Root Causes of the Power Interruptions

There are switching devices (ARCBs and LBS) installed in these feeders for better operation and maintenance flexibility. In order to address the reliability issue of the feeders, following remedial and corrective measures are proposed:

a) 33kV Drugyel Feeder

The circuit length of this feeder is 127.17km (longest of all the feeders) and some sections of the feeder pass through thick vegetation and rugged terrain. The feeder terminates from Olathang substation and is extended as far as Lingzi under Thimphu Dzongkhag. The feeder recorded SAIFI & SAIDI of 3.11 & 9.47 on average for recent three years. Currently, there is an ARCB and LBS installed in this feeder and it is unfortunate the ARCB functions like an isolator. Any fault that occurs beyond this switching equipment is also experienced by the upstream customers. Therefore, it is inevitable to have control mechanisms such as ISDs and need to reconfigure the sources and feeders (if required) so that the faults are not encountered in the entire feeder.

b) 33kV Shaba Feeder

This feeder is the most susceptible feeder of all the feeders under Paro Dzongkhag in reliability front. The reliability indices are 10.22 & 15.34 for SAIFI & SAIDI respectively. The poor reliability indices for this feeder in comparison to rest of the feeders may be due to but not limited to longer circuit length, more loads connected to the feeder. More interruptions could be also hypothesized due to no switching and control equipment installed in the feeder. Any fault in the network could have led to entire blackout and accordingly the reliability indices.

The remedial and corrective measures to improve the reliability parameters for the above feeders are proposed in **Section 8** although similar proposals have been proposed for other feeders also.

7.2.4 Single Phase to Three-phase Conversion

BPC during the RE expansion programs considered for low-load remote and rural homes with two of the three-phases of the MV designed with single phase transformers. However, with the adoption of mechanized agricultural machinery, the requirement of three-phase power to cater these loads is gaining an importance even in the rural areas. Therefore, R&DD, BPC in 2017 has carried out the "Technical and Financial Proposal on Converting Single Phase to Three-phase Supply" to come out with the alternatives for providing three-phase power supply where there are single phase power supplies. It was reported that while all the alternatives required the third conductor of the MV system to be extended on the existing poles following three proposals along with the financial impact were proposed:

a) Alternative -I

It was proposed to replace all the single-phase with three-phase transformers and this option as contemplated as not feasible as a replacement by three-phase transformers and distribution boards will lead to idle storage of single phase transformers of BPC.

b) Alternative -II

It was proposed to utilize the existing single-phase transformers to form three-phase transformations along with the additional purchase of three-phase transformers and additional pole structures. Further, single phase transformers of identical make, type, and rating can be only used to make three-phase power available.

c) Alternative -III

Option 3 is found to be a techno-commercially viable alternative as the lines can be easily upgraded to three-phase by constructing third conductor on existing pole structures. The transformer can be upgraded from single phase to three-phase as and when the demand for 3-phase supply comes. The line up-gradation across the country would amount to Nu. 96.67 million (Detail in **Annexure-6**) excluding the cost of three-phase transformers which have to be procured on need-basis, rather than one-time conversion in general.

The total single-phase line length required to be converted to three-phase in the Dzongkhag is 39.71 km and the estimate for such conversion would require Nu. 4.99 Million.

As the single phase to three network conversions is a demand-driven planning, conversions works shall be carried out based on the demand from the customers which would be more techno-commercially viable alternatives. Therefore, considering the anticipatory conversion requirement, the conversion of networks is proposed in the later stage of the DSMP.

7.3 Assessment of Distribution Transformers

7.3.1 Distribution Transformer Loading

The DTs are one of the most critical equipment of the distribution network and assessment of loading pattern along with the remaining asset life are crucial to ascertain the adequacy and performance of the transformer. The capability evaluation is based on historical peak load loading pattern and forecasted peak load growth of the feeder.

As per the peak loading pattern, some of the existing transformer capacities would not be adequate to cater the forecasted load growth for next ten (10) years. Accordingly, the capacities of the transformers need to be up-graded and such proposal is tabulated in **Table 13**. The individual DT loading details used to derive the summary is attached as **Annexure-7**.

Table 13: Forecasted Transformer Loading

Sl. No.	Name of Feeder	Capacity (kVA)	Peak Load (kVA)	2019% Loading	Peak load 2025(kVA)	% 2025 Loading	Peak load 2030(kVA)	% 2030 Loading
1	Issuna 1(near main road)	63	61	97%	67	106%	72	114%
2	Tshongkha village	100	76.5	77%	102	102%	107.1	107%
3	Lagay	63	45.74	73%	73.7	117%	97	154%
4	RBA 2	500	393.84	79%	510.00	102%	607.00	121%
5	Upper Jangtoena	63	100	159%	106.00	168%	111.00	176%
6	Chang Dungka I	100	58	58%	106.00	106%	146	146%
7	Shaba high school	125	194.88	156%	194.88	156%	194.88	156%
8	Gup Tshering orchard	63	77	122%	77	122%	77	122%
9	Shab Shelgo	63	108.24	172%	168.00	267%	218.00	346%
10	Drugidingkha I	100	65.04	65%	96	96%	122	122%
11	Dzongdrakha I	63	94	149%	94	149%	94	149%
12	Woochu	160	234.6	147%	393	246%	525	328%
13	BAFRA	125	62	50%	110	88%	150	120%
14	Damtsibu/Tashi Namgay Resort	500	320	64%	506	101%	661	132%
15	Nyemjo Regitsawa	63	48	76%	66	105%	81	129%
16	Upper Lamgong	125	60.207	48%	80	64%	130	104%

Sl. No.	Name of Feeder	Capacity (kVA)	Peak Load (kVA)	2019% Loading	Peak load 2025(kVA)	% 2025 Loading	Peak load 2030(kVA)	% 2030 Loading
17	Chunju	63	40.28	64%	62.6	99%	81.2	129%
18	Yamji	63	50	79%	86	137%	116	184%
19	Taktshang	100	39.46	63%	57.1	91%	71.8	114%
20	Tshenshi	63	95.58	96%	115	115%	131	131%
21	Nichiphu	125	145.92	117%	258	206%	351	281%
22	Kitchu resort	160	164	103%	164	103%	164	103%
23	Gonju	250	190.3	76%	351	140%	484	194%
24	Dagophu	250	109.6	44%	274	110%	411	164%
25	Dop Duzhi	63	51.78	82%	63.3	100%	72.9	116%
26	Dotey school	63	45	71%	63	100%	75	119%
27	Kinga school	63	77.68	123%	118	187%	152	241%
28	Kitchu	250	180	72%	225	90%	250	100%
29	Lower Ngoba	160	87.84	55%	150	94%	202	126%
30	Naktsel resort	500	289	58%	500	100%	595	119%
31	Shari Bara	250	212	85%	250	100%	300	120%
32	Old Pema Tshongkhang II	500	456	91%	792	158%	1072	214%
33	Dago old B mobile I	500	300	60%	400	80%	500	100%
34	Sunday Market I	1000	700	70%	750	75%	1000	100%
35	Kwangchow Wood Tech	500	316.9	63%	498	100%	648	130%
36	Upper Gaptey	250	229	92%	250	100%	350	140%
37	Drangzhi Goenpa	63	52.88	84%	72.2	115%	88.3	140%
38	Chumina	100	80.98	81%	138	138%	185	185%
39	Upper Khangkhu	315	218	69%	284	90%	339	108%
40	Druk Air hanger	500	247.12	49%	508	102%	725	145%
41	Druk Air I	1600	1093	68%	1597	100%	2017	126%
42	Nemi Zampa	250	225	90%	300	120%	400	160%
43	Redfort Uma	160	71	44%	143	89%	203	127%

Assuming that the load growth of the rural homes is not expected to grow similar to that of urban dwellings, it is strongly recommended to closely monitor the actual load growth and accordingly plan remedial measures for those transformers although some of the transformers would get overloaded as per the forecasted load. Nevertheless, considering the actual site-specific growth rate and judgment of the field offices, it is recommended that arrangements be made for the up-gradation of 24 out of 43 transformers. However, cross-swapping the existing transformers prior to procurement of new transformers would mean that, only twelve (12) transformers have to be procured tabulated in **Table 14**.

Table 14: Proposed Lists of DTs Requiring Up-rating

Sl.No.	Name of Feeder	Capacity (kVA)	Peak Load (kVA)	% Loading	Proposed kVA	Adjustment/New
	List of Transformer for 2019					
1	Upper Jangtoena	63	100	159%	125	Adjustment-Shaba Hss DT
2	Shaba high school	125	194.88	156%	250	Adjustment-Upper Gaptey DT
3	Shab Shelgo	63	108.24	172%	250	Adjustment-Gonju DT
4	Dzongdrakha I	63	94	149%	160	Adjustment-Woochu
5	Woochu	160	234.6	147%	250	Adjustment-Nemi Zampa
6	Nichiphu	125	145.92	117%	500	New
7	Kinga school	63	77.68	123%	125	Adjustment-Nichiphu
8	Old Pema Tshongkhang	500	456	91%	1000	New
9	Upper Gaptey	250	229	92%	500	New
10	Nemi Zampa	250	225	90%	500	Adjustment-Old Pema Tshongkhang DT
11	Gonju	250	190.3	76%	500	New
	List of Transformer for 2025					
1	Chang Dungka I	100	106	106%	160	New
2	Gup Tshering Orchard	63	77	122%	125	Adjustment-Chumina
3	RBA 2	500	510	102%	1000	New
4	Shari Bara	250	250	100%	500	Adjustment-RBA 2
5	Wangchuk Wood Tech	500	498	100%	1000	New
6	Drangzhi Goenpa	63	72.2	115%	500	Adjustment-Wangchuk Wood Tech
7	Chumina	100	138	138%	250	Adjustment-Shari Bara
8	Tshenshi	63	115	115%	250	New
9	Lagay	63	73.7	117%	125	Adjustment-Chang

Sl.No.	Name of Feeder	Capacity (kVA)	Peak Load (kVA)	% Loading	Proposed kVA	Adjustment/New
						Dungkha-I
10	Druk Air hanger	500	1093	145%	725.00	New
	List of Transformer for 2030					
1	Nyemjo Regitsawa	63	81	129%	100	New
2	Chunju	63	81.2	129%	250	New
3	Yamji	63	116	184%	125	New
	Total number of transformers required to up-grade				**24**	
1	Extra Transformers	63	4	2019-2025		**Can cross check with the nearest ESDs for adjustment**
		63	4	2025-2030		
		500	1	2025-2030		
		63	3	2030-		
	Total extra		**12**			

7.3.2 Asset life of Distribution Transformers

The DTs are one of the most critical equipment of the distribution network. Therefore, assessment of existing loading pattern together with the remaining asset life is crucial to ascertain its capabilities to cater the projected load growth. The life cycle of transformer and its mapping provides the clear information for its optimal utilization and development of an asset replacement framework.

As listed in **Table 15,** for the DTs that outlived its asset life expectancy, proper evaluation and testing should be prerequisite for their continued utilization.

Table 15: List of Outlived Transformers

Sl. No.	Name of Location	Unit	Qty	Cap. Date	No. of Years put to Use	Serial Number
1	315kVA, 11/0.400kV - Lower Jagarthang	NO	1	7/1/1985	34.52	KT-315/199
2	315kVA, 11/0.433kV - Hotel Olathang	NO	1	7/1/1985	34.52	36465

Sl. No.	Name of Location	Unit	Qty	Cap. Date	No. of Years put to Use	Serial Number
3	250KVA, 11/0.433kV - Kichu	NO	1	7/1/1989	30.52	B/4148
4	250KVA, 11/0.415kV - Traning Centre AMC	NO	1	7/1/1986	33.52	SIFD-07-066
5	160KVA, 11/0.415kV - Woochu	NO	1	7/1/1988	31.52	86 DD-069/101988
6	160kVA, 11/0.415kV - Shab Denkha	NO	1	7/1/1988	31.52	86DD-069/8
7	160kVA, 11/0.433kV - Upper Paro	NO	1	7/1/1987	32.52	86 DD-069/7
8	160KVA, 11/0.433 kV - Taa Dzong	NO	1	7/1/1988	31.52	86-87-369
9	100kVA, 11/0.433kV - Chumina	NO	1	7/1/1988	31.52	86BD-160/11
10	100kVA, 11/0.415kV - Tshenshi	NO	1	7/1/1987	32.52	2026
11	100kVA, 11/0.415kV - Nemjo Tshekha	NO	1	7/1/1987	32.52	86 BD- 069/7
12	100KVA, 11/0.415kV - Old Bondey	NO	1	7/1/1990	29.52	BD-180/15
13	100kVA, 11/0.433kV - Shari Kempa	NO	1	7/1/1988	31.52	NA
14	125kVA, 11/0.415kV -Lango School	NO	1	7/1/1988	31.52	2009-12-11-10442
15	125 KVA, 11/0.415kV - Way to Drujidingkha	NO	1	7/1/1982	37.52	8200/8075
16	125kVA, 11/0.400kV - Hotel Pelri Cottage	NO	1	7/1/1990	29.52	NA
17	63kVA, 11/0.433kV - Jangsa EPI	NO	1	7/1/1988	31.52	88BD-160/9
18	100kVA, 11/0.415kV - Shingkhana	NO	1	7/1/1988	31.52	86BD-160/7
19	100kVA, 11/0.415kV - Shab Bara	NO	1	7/1/1988	31.52	86BD-160/13
20	100kVA, 11/0.415kV - Hephu	NO	1	7/1/1988	31.52	86BD-160/17
21	63 KVA, 11/0.415kv - Gaupay	NO	1	7/1/1988	31.52	3805/13-14
22	63kVA, 11/0.433kV - Kuengachoeling	NO	1	7/1/1990	29.52	78413
23	160kVA, 11/0.433kV - Kuduphu	NO	1	7/1/1986	33.52	NA
24	250kVA, 11/0.415kV - Gonju	NO	1	7/1/1989	30.52	S/4144
25	125kVA, 11/0.433kV - Gangtey Village	NO	1	7/1/1988	31.52	NA
26	125kVA, 11/0.415kV - Old Capps Office (TTC-OLD)	NO	1	7/1/1988	31.52	86BD-160/16
27	250kVA, 11/0.415kV - Tomja	NO	1	7/1/1989	30.52	S/4141
28	100kVA, 11/0.415kV - Jangtona	NO	1	7/1/1988	31.52	NA
29	100kVA, 11/0.415kV - Chhuba	NO	1	7/1/1988	31.52	3997
30	83kVA, 11/0.415kV - Chang Dungkha	NO	1	7/1/1988	31.52	88-AD-125/4
31	50kVA, 11/0.415kV - Eitha Gonpa	NO	1	7/1/1979	40.53	07-010863-02
	Total transformers		**31**			

7.3.3 Replacement of Single Phase Transformers

As discussed in the "Single Phase to Three-phase Conversion" of the distribution network it will be more economical and technically feasible to convert the single to three-phase transformers on need basis. Total of Nu. 283.00 million is estimated for replacing all single-phase transformers including the distribution board. The detailed work out is produced as **Annexure-8.**

There are 17 single phase transformers in the Dzongkhag and the estimate for up-grading all the single to three-phase transformers would require Nu. 3.27 Million. As the conversion from single to three-phase transformer is demand base, the plan has been distributed in ten year-span.

7.4 Power Requirement for Urban Areas by 2030

Paro town has an area of approximately 20 acres of land (LAP-I) and the office of the Census Commissioner's preliminary report places approximately 43,167.00 (5.6%) of the total population is in Paro Dzongkhag. The areas under the LAP-I are core town area with total of 314 plots allocated. Unlike other major towns, the extensions of town have been growing just marginally due to presence of international airport where the structures are restricted to certain height and limited to certain boundaries. Similarly, due to conservative polices on food self-sufficiency, the agricultural and arable lands are preserved restricting any town expansions. This in turn has resulted in developmental activities being steady over the years. Nevertheless, due to international airport and being hot spot for tourists, it is anticipated to continue the steady growth of the town exclusively in the extended areas.

The LAP boundary extends Dopshari Gewog in the west, Nemizampa Gewog in the south and Wangchang Gewog in the east and north as shown in **Figure 8**. Further, the Dzongkhag has initiated a "Paro Valley Development Plan" to promote an integrated planning and development for ensuring efficient and shared use of resources and infrastructure services.

i. Existing Distribution Network and Scenario

a) Existing Infrastructure

Out of 314 plots allocated under LAP-I, almost all the plots have buildings either completed the construction or in the verge of completion. The basic amenities such as accessible road, drainage, sewerage system and footpath have also completed in most of the areas and initiated in rest of the areas.

b) Existing Distribution Network

Currently, the Paro town is fed from outgoing 11kV Town feeder of 33/11 kV, 2X5 MVA Tshongdu substation and 11kV Tshendona feeder of 33/11kV, 2x5MVA Jangsa substation. The feeders are constructed with overhead bare conductor (Rabbit), UG XLPE 150 sq.mm and HV ABC (3x95sq.mm). There are eight transformers with installed capacity of 4.81 MVA for customers as shown in **Table 16**. The peak load of the Paro town recorded as on 2019 is 2.99 MW.

Figure 8: Distribution Network of Paro

Table 16: Total Number of Transformers and its Installed Capacity for Paro town

Sl. No.	Name of Transformer Location	Installed Capacity (kVA)	Location	Customer
1	Old Pema Tshongkhong I	500	Core town area	1209
2	Old Pema Tshongkhong II	500		
3	Sunday market I	500	Core town area	

Sl. No.	Name of Transformer Location	Installed Capacity (kVA)	Location	Customer
4	Sunday Market II	1000	Core town area	
5	Sunday Market	63	Core town area	
6	Dago building I	500	Core town area	
7	Dago building II	500		
8	Behind Hotel Jigmeling	1000	Core town area	
	Total	**4,563.00**		

The installed distribution transformer capacity (load) works out to be 3.88MW (4.563MVA @0.85 pf) and would be adequate to meet the load requirement till 2030 as it is anticipated to reach the load growth of 4.81MW if assessed individually. However, the 33/11kV Tshongdue substation may not be adequate to cater the entire load connected to the outgoing feeders of the substation as it is forecasted to reach 10.44MW & 12.51MW in 2025 & 2030 respectively against the installed capacity of 10MVA (8.5MW @0.85 pf). As reflected in **Section 7.3.2**, it is not possible to simply add another transformer due to space constraints. Therefore, it is proposed to install 10MVA to meet the requirement and use the existing 5MVA in Shaba substation (which would also require capacity up gradation).

ii. Re-sizing of conductor and conversion works

a) Construction of UG network

The 33kV Olathang to Tshongdue feeder is 1.00km (circuit length) and the arrangement is LILO from Tshongdue substation to 33/11kV Jangsa substation. These two substations take cares one third of the customers, half of the load and more significantly the important customers of Paro Dzongkhag (Airport, Paro main town, NIE and Dzong areas). Should there be any power interruption in this feeder mean that 33.33% of the customers will be without power supply. Therefore, it is proposed to construct additional feeder through UG (as obtaining RoW will be an issue) from Olathang to Tshongdue substation as a contingency plan.

b) Conversion of ACSR to LV ABC

The LV networks in and around Paro are constructed through ACSR bare conductor which possess great risk to public and to other inhabitants (safety). Therefore, it is proposed to convert LV ACSR bare to LV ABC conductor in and around Paro in phase wise manner.

c) Construction of dedicated feeder for NIE & Airport

Paro Airport and NIE are the two most important customers in Paro Dzongkhag requiring reliable and quality power supply round the clock. Therefore, it is proposed to construct a dedicated feeder which will not only improve the reliability of the power supply, it will also restrain itself from other faults by this arrangement.

d) Control Panels and Breakers

The existing 3 numbers of 11kV, VCB control panels of Tshongdue substation had worn out over the years and poses great risk to the operators and to the equipment. Since, they were installed in 1980s, the panels are obsolete, and the spare parts are not readily available in the market. Therefore, it is proposed to replace by 2 numbers of 4-way 11kV RMUs which is expected to ease while operating and greatly enhance the safety of the operators and equipment.

8. Distribution System Planning

The distribution network of the Dzongkhag has a radial topology with significant risk of high interruptions (fault in one location would mean that the entire customer in the network would experience the outage). Having alternate routes, sources or any contingency plan would significantly improve the reliability and power quality. In order to have robust and hard-lined distribution network, there is a need for good contingency plans with adequate sources to reduce the downtime. However, any provision to improve the power system would incur additional capital cost in addition to recurring additional preventive and corrective costs.

Therefore, to meet the system shortfalls against the set standard and to keep abreast with the forecasted load growth, proper distribution system planning is required which are detailed from **Section 8.1** through **Section 8.4.**

8.1 Power Supply Sources

8.2.1 HV Substation

As detailed in **Section 7.1.1,** the 66/33kV Olathang and 66/33/11kV Pangbesa HV substations would be adequate to meet the power requirement till 2030.

8.2.2 MV Substations

Although, the HV substations would be adequate to meet the increasing load requirement, the MV substations may not be adequate as detailed in **Section 7.1.2**. Therefore, it is proposed to up-grade the capacities of the two substations as shown in **Table 17.** The MV substation up-grading proposal would require arrange/procure only 10MVA transformer as one of the existing 5MVA transformers can be used to up-grade the Shaba substation.

Table 17: Proposed up-grading of MV substations

Sl. No.	Name of Substation	Source Capacity		Forecasted Load (MW)		
		Existing	Proposed	2019	2025	2030
1	33/11kV Shaba Substation	5	10	4.07	5.39	6.50
2	33/11kV Tshongdue Substation	10	15	8.32	10.44	12.51
3	33/11kV Jitsiphu Substation	5	7.5	2.96	3.93	4.74
	Total	**30**	**25.50**	**19.38**	**25.40**	**30.12**

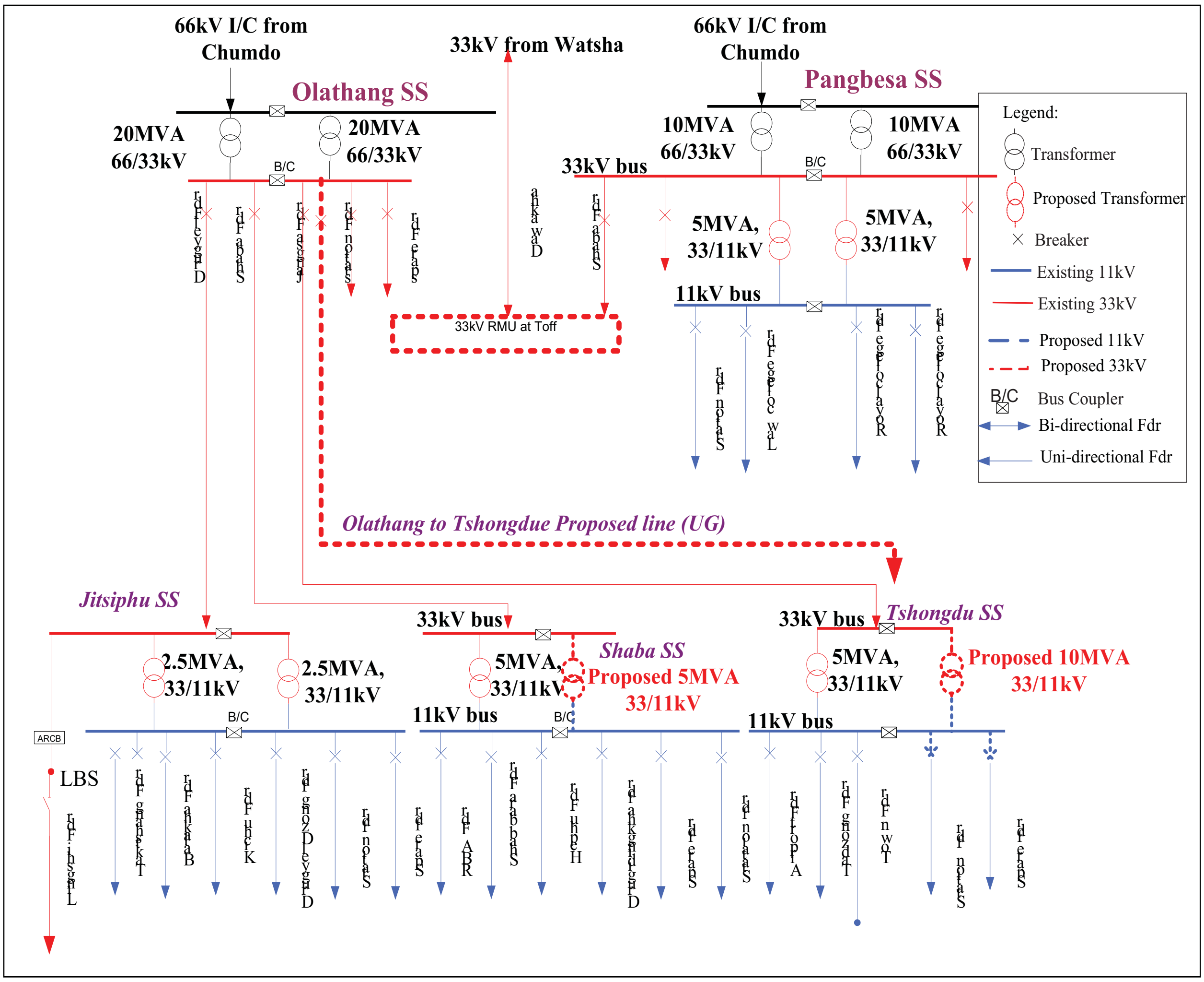


Figure 9: Proposed distribution network

8.2 MV and LV Lines

a) Construction of dedicate line for NIE and airport

In order have reliable power supplies to the customers of NIE and airport, it is proposed to construct a dedicated feeder (2.00km approximately);

b) Construction of UG network (Olathang to Tshongdue)

In order to have contingency plan for the customers of main town, airport, NIE and other extended areas from the town, it is proposed to construct additional feeder from Olathang to Tshongdue substation through UG (approximately 1.00km);

c) Conversion of ACSR to LV ABC

The LV networks in and around Paro are constructed through ACSR bare conductor which possess great risk to public and to other inhabitants (safety). Therefore, it is proposed to convert LV ACSR bare to LV ABC (4CX50 sq.mm & 4CX95 sq.mm) conductor in and around Paro in phase wise manner (15km approximately); and

d) Re-Sizing of the Conductors

The 11kV Drujidingkhag and Kichu Feeders require improving the voltage profile either by re-sizing the conductors or by installing the voltage boosters/regulators.

8.3 Distribution Transformers

As listed in **Section 7.3.1,** the listed transformers need to be up-graded either by procuring or by swapping the required capacities. Out of 24 listed transformers, procurement of only 12 DTs would be required which has been worked out based on the likelihood of load growth of the areas and inculcating the fair judgment of the field offices.

Table 18: List of Distribution Transformers which needs to be Up-Graded

Sl.No.	Name of Feeder	Capacity (kVA)	Peak Load (kVA)	% Loading	Proposed kVA	Adjustment/New
	List of Transformer for 2019					
1	Nichiphu	125	145.92	117%	500	New
2	Old Pema Tshongkhang	500	456	91%	1000	New
3	Upper Gaptey	250	229	92%	500	New
4	Gonju	250	190.3	76%	500	New
	List of Transformer for 2025					
1	Chang Dungka I	100	106	106%	160	New
2	RBA 2	500	510	102%	1000	New
3	Wangchuk Wood Tech	500	498	100%	1000	New
4	Tshenshi	100	138	138%	250	New
5	Druk Air hanger	500	1093	145%	725.00	New
	List of Transformer for 2030					

<table>
<tr><th>Sl.No.</th><th>Name of Feeder</th><th>Capacity (kVA)</th><th>Peak Load (kVA)</th><th>% Loading</th><th>Proposed kVA</th><th>Adjustment/New</th></tr>
<tr><td>1</td><td>Nyemjo Regitsawa</td><td>63</td><td>81</td><td>129%</td><td>100</td><td>New</td></tr>
<tr><td>2</td><td>Chunju</td><td>63</td><td>81.2</td><td>129%</td><td>250</td><td>New</td></tr>
<tr><td>3</td><td>Yamji</td><td>63</td><td>116</td><td>184%</td><td>125</td><td>New</td></tr>
<tr><td></td><td colspan="4">Total number of transformers required to up-grade</td><td>12</td><td></td></tr>
<tr><td rowspan="4">1</td><td rowspan="4">Extra Transformers</td><td>63</td><td>4</td><td colspan="2">2019-2025</td><td rowspan="4">Can cross check with the nearest ESDs for adjustment</td></tr>
<tr><td>63</td><td>4</td><td colspan="2">2025-2030</td></tr>
<tr><td>500</td><td>1</td><td colspan="2">2025-2030</td></tr>
<tr><td>63</td><td>3</td><td colspan="2">2030-</td></tr>
<tr><td></td><td>Total extra</td><td></td><td>12</td><td colspan="2"></td><td></td></tr>
</table>

8.4 Switching and Control

Switching and control system is required to take care of the system during faulty situations which ultimately is going to take care of the failure rate, repair and restoration time. This in turn would improve the reliability, safety of the equipment and online staff, optimizes the resource usage and more importantly the revenue generation will be enhanced. Similarly, in order to capture the real time data and information, it is inevitable to have automated and smart distribution system. The feeders which are more susceptible to faults are identified with proposed restorative measures through the studies. With the exception of tripping of breakers in the sending end substations, existing distribution network is neither automated nor smart to detect the faults and respond in real-time manner. The automation and smart grid components are detailed in Smart Grid Master Plan 2019.

8.4.1 Intelligent Switching Devices

Unlike other Dzongkhags, Paro being situated between mid-Montana to alpine zones, the Dzongkhag has coniferous forests in the valleys and with little or no trees near the alpine zones. Therefore, power interruptions due to tree falling and landslides are minimal as is the case in central, eastern and southern part of the country. Therefore, the Dzongkhag has good reliability indices compared to rest of the Dzongkhags.

However, as reflected in **Section 7.2.3,** 33kV Drugyel and 33kV Shaba feeders are the most susceptible feeders. Therefore, additional preventive and corrective measure for these feeders needs to be put in place. In order to improve reliability and power quality of these feeders, it is proposed to have technology in place to respond to fault and clear it accordingly rather than through ex post facto approach. Therefore, it is proposed to enhance the existing switching and control system by having latest suitable and user-friendly technology (automatic). The coordinated arrangement of Intelligent Switching Devices (ISD) like ARCBs, Sectionalizers and FPIs would significantly improve the control and operation mechanism of the network. Figure 10 shows the existing and **Table 19** and **Figure 11** shows the proposed switching devices and RMUs for the distribution network for easing operation and maintenance and for improving the reliability of the power supply of the Dzongkhag.

However, the quantum and the location of the devices to be installed shall be based on the Smart Grid Master Plan 2019.

Table 19: Existing and Proposed Switching Equipment

Sl. No.	Feeder Name	ARCBs		Sectionalizers		FPIs		LBS	
		Exist	Prop	Exist	Prop	Exist	Prop	Exist	Prop
1	33kV Drugyel Feeder	1			1		4	1	0
2	11kv Shab Bara Feeder						2		2
3	11kV Drugidingkha Feeder		2		1		2		
4	11kV TA-Dzong Feeder with Dotey Feeder				2		1		
5	11kV Airport Feeder				1				
6	11kV Town Feeder		1		1		1		
7	11kV Lower Jangsa Feeder				1		1		
	Overall Total	**1**	**3**	**0**	**7**	**0**	**11**	**1**	**2**

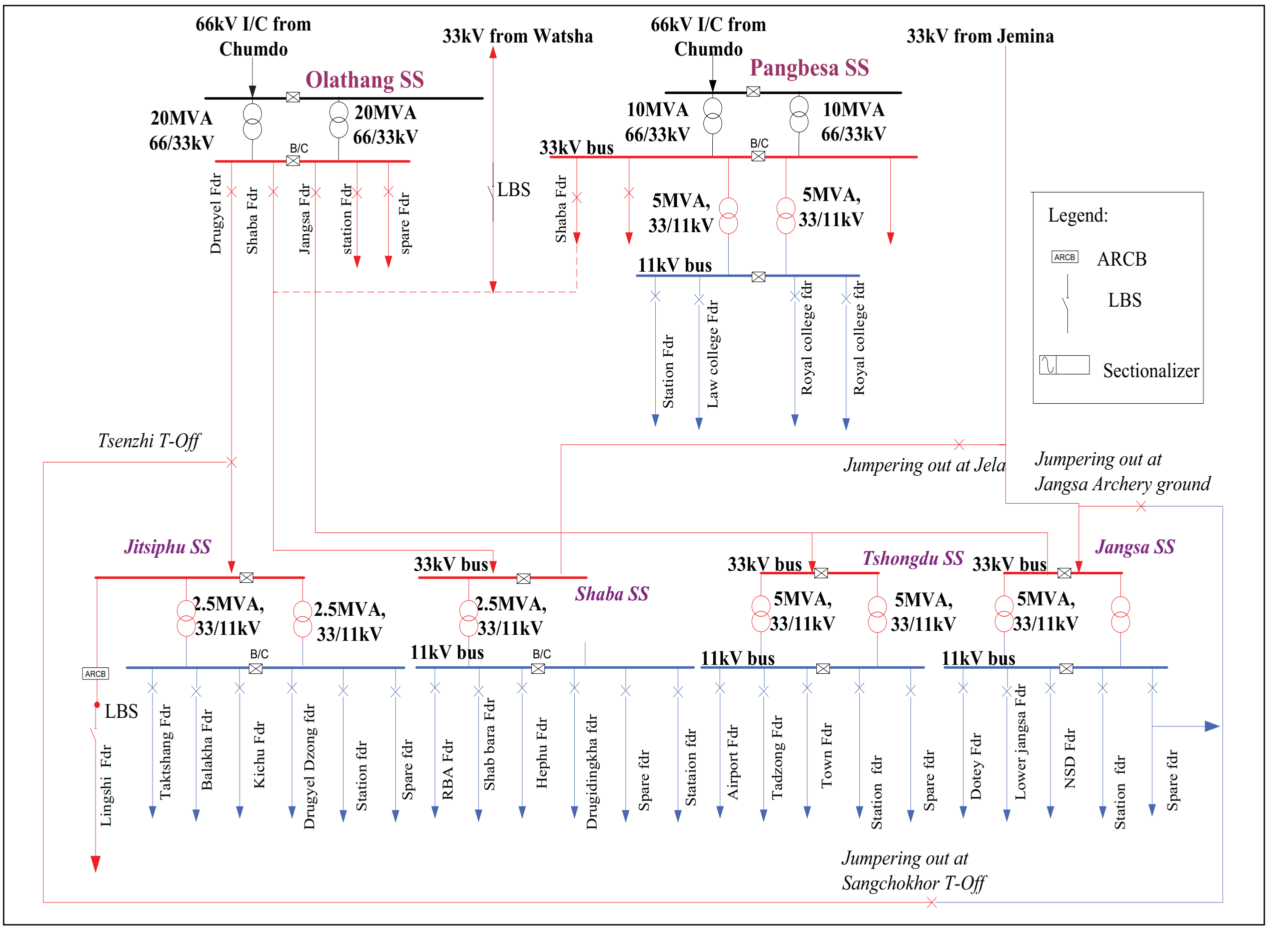


Figure 10: Existing Switching Equipment for Distribution Network of ESD, Paro

Reliability of the lines and substations can also be enhanced through training of line staff. They need to be equipped with the knowledge, skills, and the confidence to operate and maintain the distribution infrastructure. For instance, the linemen of the ESDs need to develop the confidence to change DO fuses online using hot sticks instead of the usual practice of taking shut down of the whole feeder. However, having the right tools, equipment, and especially spares (of appropriate specifications) is a prerequisite. Although it is not possible to quantify the reliability indices that can be achieved with preventive and corrective measures in place, the proposed contingency plans would significantly improve the power quality.

Although it is not possible to quantify the reliability indices that can be achieved with preventive and corrective measures in place, the proposed contingency plans would significantly improve the un-interrupted power supply to the customers.

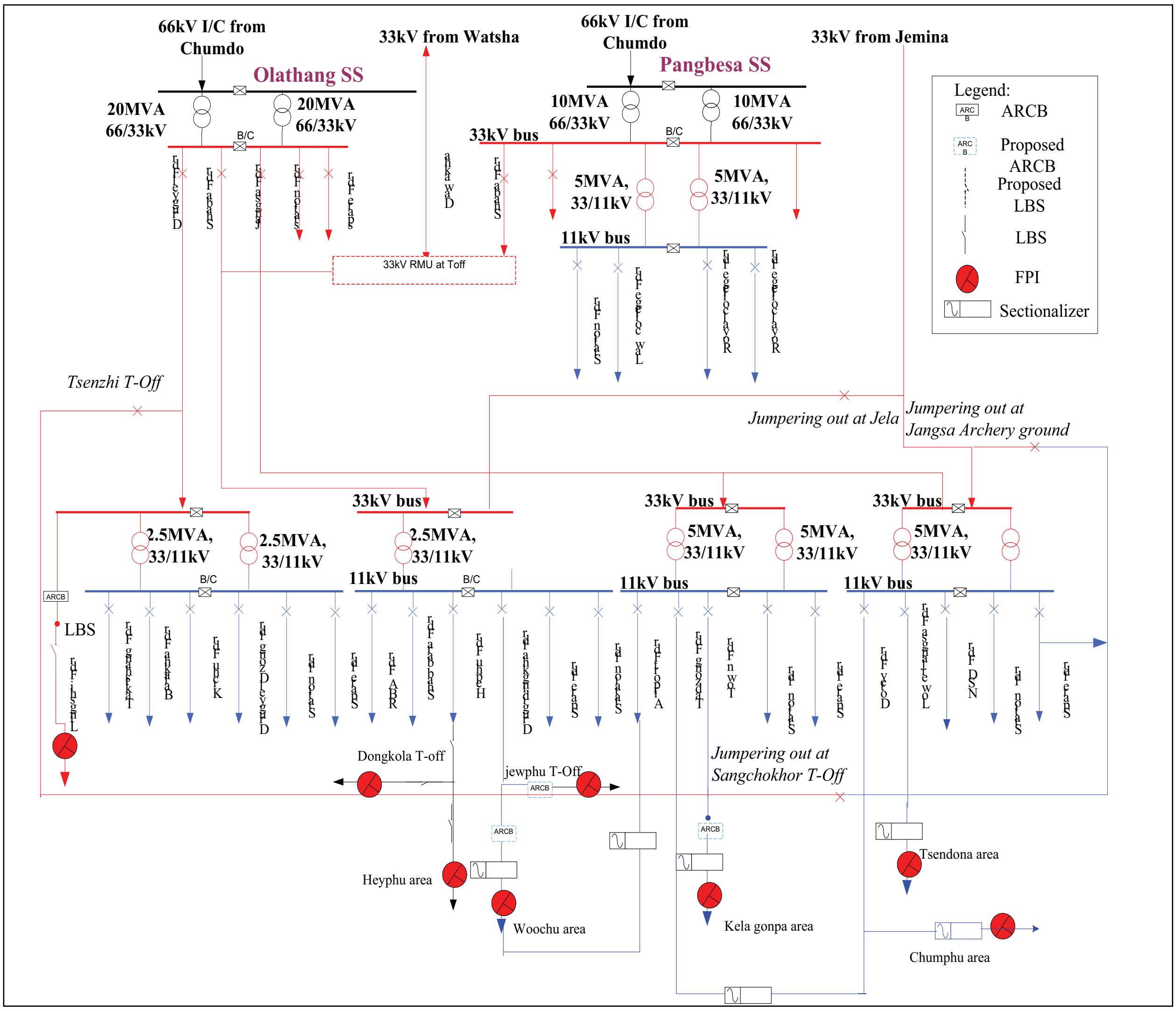


Figure 11: Proposed Switching Equipment for Distribution Network of ESD, Paro

8.4.2 Distribution System Smart Grid

The distribution grid modernization is outlined in Smart Grid Road Map 2019 including the investment (2020-2027). The DMS, ADMS, DSCADA features along with their components and functionalities, the timeline for the programs and the cost estimates of the smart grid are lucidly reflected. Therefore, this report exclusively entails the identification of the system deficiencies and qualitative remedial measures which would require system augmentation and reinforcement as per the existing and projected load.

9. Investment Plans

In accordance to the above mentioned contingency plans targeted to improve the power quality, reduce losses and improve reliability indices of the Dzongkhag, investment proposal is developed. The investment plan has been confined to power supply sources, MV lines, DTs, switching and control equipment and RoW.

The approved (2019-2023) investment plan and any new investment plans of ESD, Paro have been validated and synced with the system studies carried out. The annual investment plan (2020-2030) has been worked out based on the priority parameters set out as shown in **Figure 12.**

The matrix gives us the basis on the prioritization of the investments to be made in the ten-year schedule as every activity cannot be carried out at a time. The activities which have to be carried out due to load growth, developmental activities and retrofitting of obsolete/defective switchgears and equipment will have the highest level of importance and urgency. These activities have to be prioritized and invested in the initial years which are grouped in the first quadrant (Do First). Similarly, there are certain activities although might be very important but not so urgent can be planned in the later stage of the year (Do Next). These activities can be but not limited to improving the reliability, reducing losses and reconfiguration of lines and substations to reduce the losses and improving the power quality. The activities which are not so important but are highly urgent have to be also planned in later stage of the period.

How important is the task?			
	Highly Important	Action: Do First **I**	Action: Do Next **II**
	Important	**Action: Do Later III**	No Action: Don't Do **IV**
		More Urgent	**Urgent**
How urgent is the task?			

Figure 12: Priority Matrix

According to the investment prioritization matrix framework, the yearly investment plan along with the cost estimation is derived and is consolidated in **Table 20** as an investment plan. The cost estimates have been worked out based on the BPC ESR-2015 and annual inflation is cumulatively applied to arrive the actual investment cost for the following years.

In the span of next 10 years (2020-2030), the total projected investment required to adequately deliver the power to the customers of Paro Dzongkhag is Nu. 180.77 million (Nu. 18.08 million per year).

Table 20: Yearly Investment Plans (2020-2030)

Sl. No.	Project Activities	Investment Plan											Total
		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	
1	Rural Electrification (Refill In)	3.00	4.36	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	**34.36**
2	Conversion of ACSR bare conductor with LV ABC insulated cables	3.03	3.03	3.30	3.03	3.30							**15.69**
3	U-gradation of substations of Shab Drugidingkha, Shab Ravana & Bongdey)	2.33											**2.33**
4	Construction of 11kV line, AAAC (50 sq.mm)-6km, 11/0.415kV, 16kVA (2 nos) at Bumdra and Choechongtse, LV line (50sq.mm)	11.78											**11.78**
5	Construction of LV line in and around Pangbesa	10.45	0.41										**10.86**
6	Construction of 1000kVA (2 nos) USS for main academic building (Dzong) at Royal project, Pangbesa	6.54											**6.54**
7	upgradation of 11/0.415 kV, 250 kVA Gonju substation to500 kVA		1.00										**1.00**
8	upgradation of 11/0.415 kV, 125 kVA Nechiephu substation to 500 kVA			0.54									**0.54**
9	upgradation of 11/0.415 kV, 500 kVA old Pema Tshongkhong-2 substation to 1000 kVA		3.30										**3.30**
10	upgradation of 11/0.415 kV, 250 kVA upper Gaptey substation to 500 kVA					1.01							**1.01**
11	upgradation of 11/0.415 kV, 500 kVA RBA-2 substation to 1000 kVA										3.30		**3.30**

Sl. No.	Project Activities	Investment Plan											Total
		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	
12	upgradation of 11/0.415 kV, 100 kVA Changdungkha-1 substation to 250 kVA								0.88				**0.88**
13	upgradation of 11/0.415 kV, 500 kVA Wangchuk Wood Tech substation to 1000 kVA									3.30			**3.30**
14	Upgradation of 11/0.415 kV, 500 kVA Ddrukair Hanger substation to 1000 kVA							3.30					**3.30**
15	upgradation of 11/0.415 kV, 100 kVA Tshenzi substation to 250 kVA										0.89		**0.89**
16	upgradation of 11/0.415 kV, 63 kVA Nemjo Regitsawa substation to 100 kVA											0.54	**0.54**
17	upgradation of 11/0.415 kV, 63 kVA Chunju substation to 250 kVA											0.88	**0.88**
18	Upgradation of 11/0.415 kV, 100 kVA Yemji substation to 125 kVA											0.54	**0.54**
19	Construction of UG 3CX150 sq.mm Drukair and NIE Feeder	4.50											**4.50**
20	Construction of 33/11kV, 5 MVA Shaba SS					7.85							**7.85**
21	Installation of 11kV (5 nos) and 33kV (5 nos) LBS in and around Paro	4.50	0.10										**4.60**
22	Upgradation of 10kms of 11kV Kichu Feeder from ACSR Rabbit to ACSR Dog line OR propose to install Voltage Regulator				3.00								**3.00**
23	Upgradation of 11kV Drujidingkha feeder from ACSR Rabbit to Wolf OR propose to install				3.00								**3.00**

Sl. No.	Project Activities	Investment Plan											Total
		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	
	Voltage Regulator												
24	Construction of 1x10MVA Tshongdu SS					39.25							**39.25**
25	Construction of UG 3CX150 sq.mm Olathang to Tshongdu Feeder						2.24						**2.24**
26	Construction of 33kV RMU at Shaba		5.10										**5.10**
27	Construction of 11kV RMU (2 Nos) at Town Substations			2.00									2.00
28	Conversion of single to three-phase line			0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	4.95
29	Replacement of single phase by three phase transformers			0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	**3.24**
	Total	**46.12**	**17.30**	**9.75**	**12.94**	**55.32**	**6.15**	**7.21**	**4.79**	**7.21**	**8.10**	**5.87**	**180.77**

10. Conclusion

Based on the inputs from Divisional office, validated data, assessment of the existing distribution network, and the reliability analysis, recommendations are made for system modifications and improvements. Costs associated with each recommendation are presented in several phases so that work may continue at a pace that is determined by fund availability and the capacity of the office to execute the work. An attempt is made to prioritize the recommendations; however, there will undoubtedly be adjustments in the order and priority by which the investments will be actually implemented.

The third option which would be the leas-cost alternatives for converting the single to three-phase distribution network where all the MV lines will have to be converted to three-phase and replacing the single phase to three-phase transformers on need basis.

Although the report entails the identification of system deficiencies and reinforcement required, for automation and smart operation of the distribution network, the smart grid infrastructure development with functionalities are detailed in “Smart Grid Master Plan 2019”. Therefore, the DSMP-Smart Grid Master Plan-Hybrid is necessary which can be amalgamated during the rolling out of annual investment and budget approvals.

Proportion of LV is higher in comparison to MV line length; accordingly, the independent study carried out by BPC in 2017 showed that large portion of loss is due to LV and DT. Therefore, similar system study beyond DT has to be carried out in order to capture the entire network and strategize to develop the blue print.

11. Recommendation

Sl. No.	Parameters	Recommendations
A. Power Supply Sources		
1	33/11kV Shaba Substation	The anticipated forecasted load would reach 5.39MW & 6.50MW by 2025 & 2030 respectively against the installed capacity of 5MVA. Therefore, to meet the forecasted power demand and to supply quality power supply, it is proposed to upgrade to 10MVA. 33/11kV, 5MVA Tshongdue substation can be used to increase the installed capacity.
2	33/11kVTshongdue Substation	The anticipated forecasted load would reach 10.44MW & 12.51MW by 2025 & 2030 respectively against the installed capacity of 10MVA. Therefore, to meet the forecasted power demand and to supply quality power supply, it is proposed to upgrade to 20MVA. The existing 5MVA transformer can be used to increase the installed capacity of 33/11kV Shaba substation.
B. MV and LV Lines		
1	11kV Kichu and Drugidingkha Feeders	The Drugidingkha feeder may not be able to cater the quality power with the forecasted load. The voltage profile would not improve to the permissible range with the available options incorporated. Even re-sizing the conductor may require frequent intervention from ESD and inconveniences to the customers. Therefore, ESD may explore the other technology (AVR) to improve the voltage regulation.
2	11kV line for NIE & Airport	In order to have reliable power supply to these important customers, it is would be prudent to construct dedicated line for the two institutes.
3	Construction of 33kV UG network	33kV from Olathang to Tshongdue is the main feeder which covers half the customer of Paro and more significantly, most of the important customers are fed from this feeder. Therefore, to have contingency plan in place, it is proposed to construct additional feeder from Olathang on UG (due to RoW issue).
4	ACSR to ABC (LV)	In order to minimize the safety of the inhabitants, it is proposed to convert LV ACSR to LV ABC in and around Paro.
5	Single to Three Phase Lines	As reported in the "Technical and Financial Proposal on Converting Single Phase Power Supply to Three Phase in Rural Areas", it is recommended to convert the single to three phase lines based on need basis.
C. Distribution Transformers		

Sl. No.	Parameters	Recommendations
1	Distribution Transformer	As reflected in Section 7.3.1 of this report, it is proposed to regularly monitor the loading pattern especially of the urban transformers. It is desired to load the transformers less than 85% so as to ensure that transformer is operated at maximum efficiency. The system study is restricted to DTs, the loads needs to be uniformly distributed amongst the LV feeders to balance the load.
2	Single to Three Phase Transformers	As reported in the "Technical and Financial Proposal on Converting Single Phase Power Supply to Three Phase in Rural Areas", it is recommended to replace the single to three phase transformers on need basis.
D. Switching and Control Equipment		
1	Switching and Control Equipment	It is recommended to install Intelligent Switching Devices (ISD) like ARCBs, Sectionalizers and FPIs as proposed which would reduce the downtime for clearing faults. a) Install FPI, Sectionalizes and ARCBs at various identified locations. b) Installation of 11kV& 33kV RMUs at various identified locations.
E. others		
1	Investment Plan	As reflected in Section 9 of this report, overall investment plan as proposed is recommended.
2	Review of the DSMP	Practically the projections will hold only true in the nearest future therefor, it is strongly recommended to review the DSMP in 2025 (after five years) or if need be as and when situation demands.
3	System Studies beyond DT	It is observed that distribution of electricity is more through LV than MV & HV and the scope of DSMP terminates at DT. However, it is equally important to carry out similar system studies for LV networks till meter point. Due to time constraint and non-availability of required LV data, it is recommended to carry out the studies on LV network including the DTs. Nevertheless, with the entire distribution network captured in the GIS and ISU, the system studies should be carried out including the LV network in the future.
4	Customer Mapping	One of the important parameters required especially for reaffirming the capability of the DTs is by examining customer growth patterns. Therefore, it is recommended to consistently update the customers via customer mapping

Sl. No.	Parameters	Recommendations
		process carried out annually.
5	Right of Way	RoW should be maintained as per the DDCS 2016. However, increased frequency of RoW clearing in the problematic sections of the line and in fast growth sub-tropical forest is recommended.
7	Asset life of DTs	The asset life of DTs needs to be gathered to enable development of asset replacement framework. However, it is recommended to regularly monitor the health of the transformers which have already outlived their lives.
8	Overloading of DTs	As per the load forecast, some of the rural DTs might overload. While the probability of realizing such an event is quite low. It is, however, recommended that the DTs that have already exhausted its statutory life (25 years and above) be regularly monitored.
9	New extension through 33kV network	The power carrying capacity of 33kV system is almost 3-fold compared to that of 11kV system. Therefore, any new extension of lines may be done through 33kV system (based on fund availability and practical convenience).
10	Reliability	In order to improve the reliability of the feeder/network, it is recommended that fault should be located within short period of time there by reducing the restoration time and the number of customers affected. In this regard, the following initiatives are recommended: 1) To install ISDs (communicable FPIs, Sectionalizers & ARCBs); 2) To explore with construction of feeders with customized 11kV & 33kV towers; and 3) To increase the frequency of Row clearing in a year.
11	Conversion Works	As the joint survey for laying the UG had not been done, the investment has been worked based on assumptions of likely scenarios. Therefore, ESD Paro should incorporate the actual activities during the rolling out of the investment plans.

12. Annexure

Annexure-1: MV Line Details and Single Line Diagram

Annexure-2: IS 2026, IEC 60076 (Technical parameters for Distribution Lines and Transformers)

Annexure-3: The details on load forecast methodology

Annexure-4: Detailed Simulation Results

Annexure 5: Feeder Wise Reliability Indices

Annexure-6: Material Cost for Upgrading single phase (11 kV and 33 kV) Lines to three-phase

Annexure 7: Distribution Transformer loading

Annexure-8: Material Cost of three phase (3Φ) Transformers

13. References

1. The FWPL and CPL from TD, BPC as of 2018.
2. BPC Power Data Book 2018.
3. BPC Distribution Design and Construction Standards (DDCS)-2016.
4. BPC Smart Grid Master Plan (2019-2027).
5. BPC National Transmission Grid Master Plan (2020 & 2030).
6. BPC Operation and Maintenance Manual for Distribution System (2012).
7. BPC Corporate Strategic Plan (2019-2030).
8. Population and Housing Census of Bhutan 2019.
9. The Structural Plan (2004-2027) for every Dzongkhag.
10. Paro City Development Strategy (2008).
11. Industrial Parks (Department of Industry).
12. BPC Electrical Schedule of Rates 2015.

14. Assumptions

1. All the distribution network was considered as Balanced System (Restriction with the existing ETAP Key);
2. All DTs considered as lump load and depending upon the type of load connected to the feeder, ratio of 80% (static load) to 20% (industrial feeders) were assumed;
3. The voltage level of ±10% is given as critical value which is indicated by red color while simulating and voltage level of ±5% is given as marginal value which is indicated by pink color while simulating.
4. The typical inbuilt value of X/R ratio of ETAP tool was considered for all the transformers;
5. Dimensions and parameters of some cables/UG cables are customized in the library as per the requirement;
6. The technical parameters which are required for analysis of the distribution network have been considered as per the set standard of DDCS.

15. Challenges

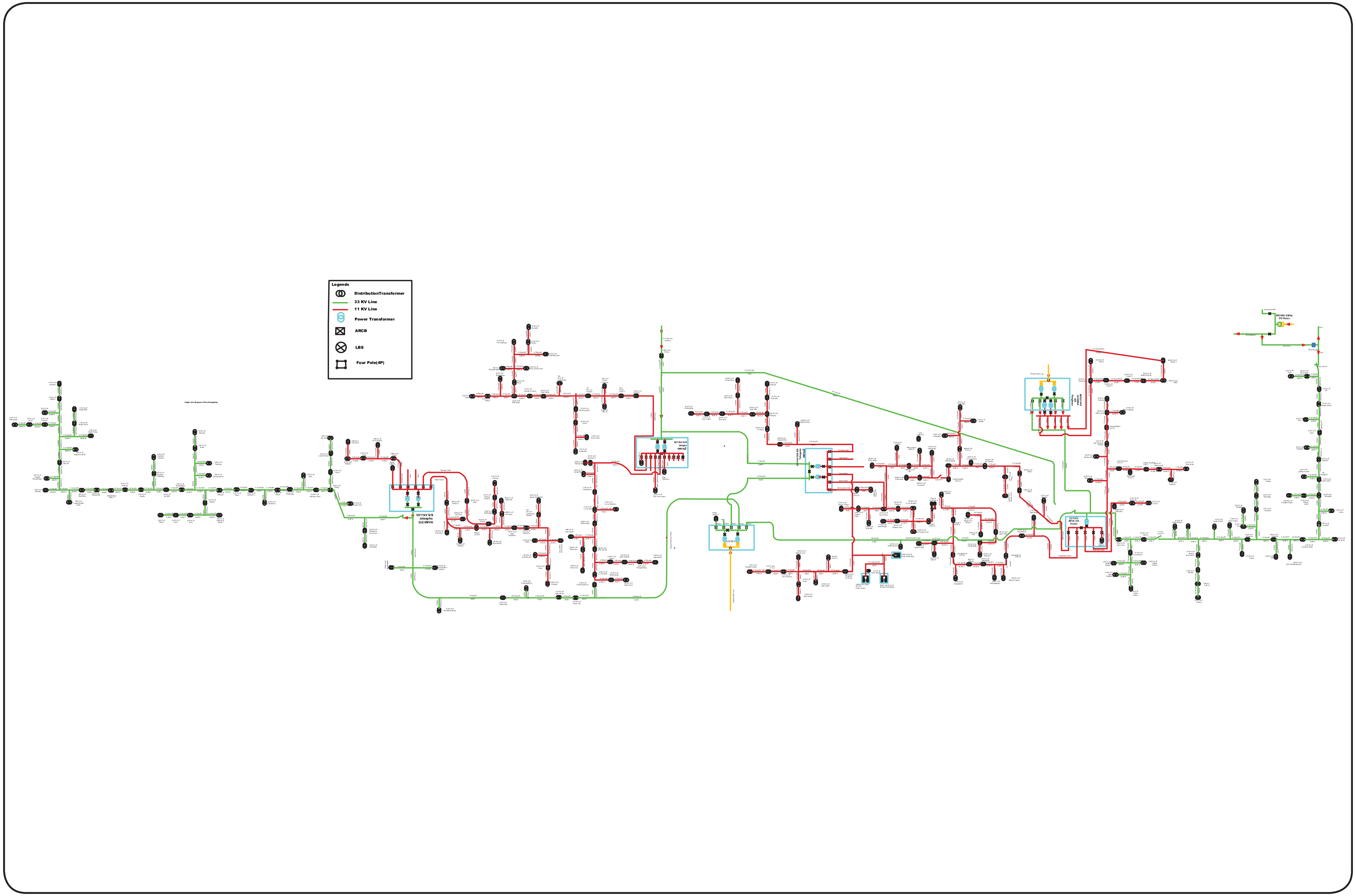
Sl. No.	Parameters	Challenges	Opportunities/Proposals
1	Software Tool (ETAP)	a) Only one key & offline Key	a) Can opt for on line key with fewer more modules specially to carry out the technical evaluation of un-balanced load flow system. This would be more applicable and accrue good result for LV networks.
		a) Balanced Load Flow	
		b) Limitations of No. of buses (1000)	
2	Data	a) No recorded data (reliability & energy) on the out-going feeders of MV SS	a) Feeder Meters could be install for outgoing feeders of MV substations to record actual data (reliability & energy)

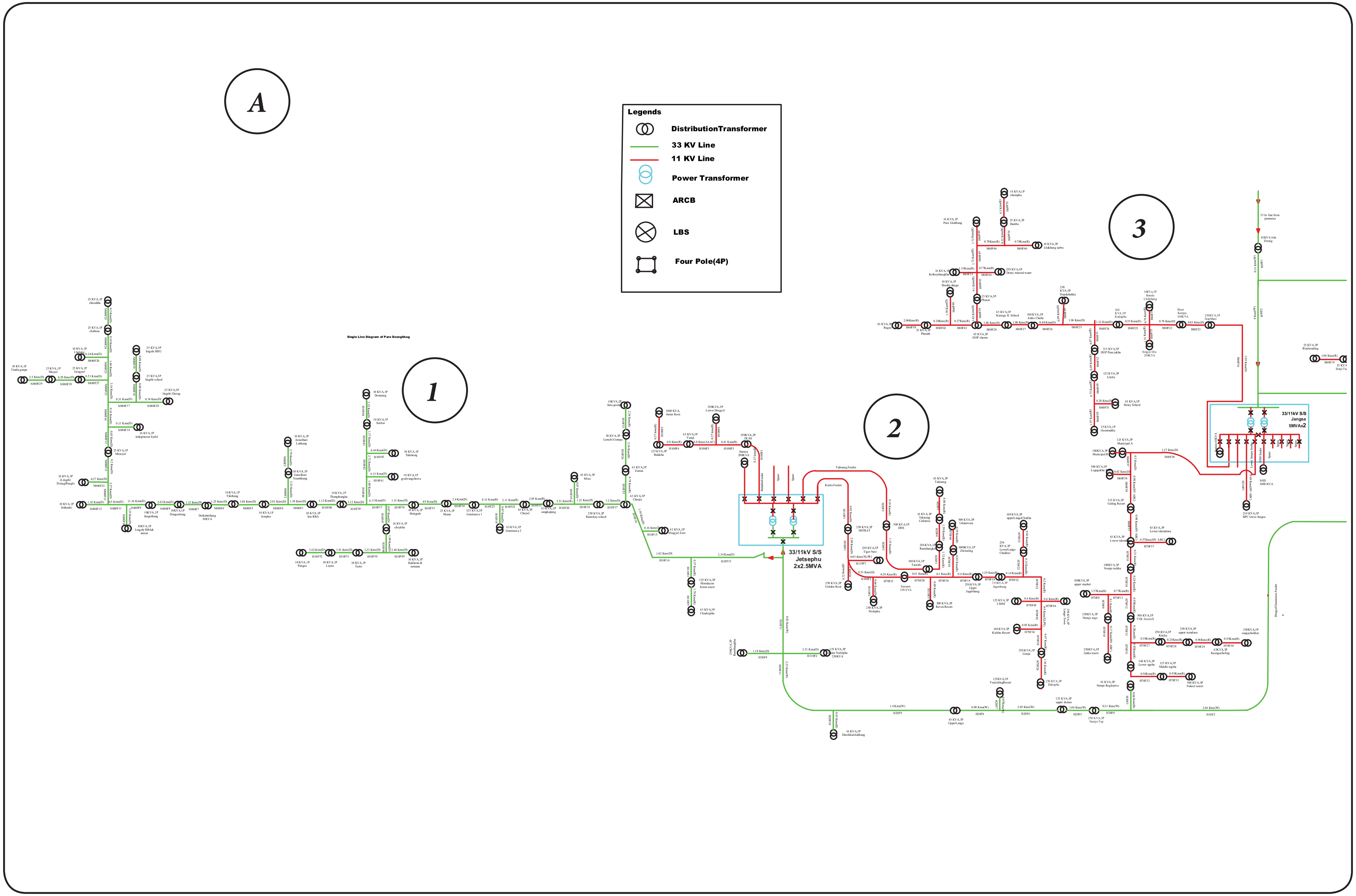
Sl. No.	Parameters	Challenges	Opportunities/Proposals
		b) Peak Load data of DTs which were recorded manually may be inaccurate due to timing and number of DTs.	b) In order to get the accurate Transformer Load Management (TLM)/loading, it is proposed to install DT meters which could also have additional features to capture other required information.
		c) No proper feeder and DT wise Customer Mapping recorded	c) Customer Information System (CIS) of the feeder/DT would enable to have proper TLM and replacement framework.
3	Manpower	a) Resource gap in terms of trained (ETAP) and adequate engineers (numbers)	a) Due to lesser number of trained engineers in the relevant fields (software), engineers from other areas were involved.

12. Annexures

Annexure-1: MV Line Details and Single Line Diagram

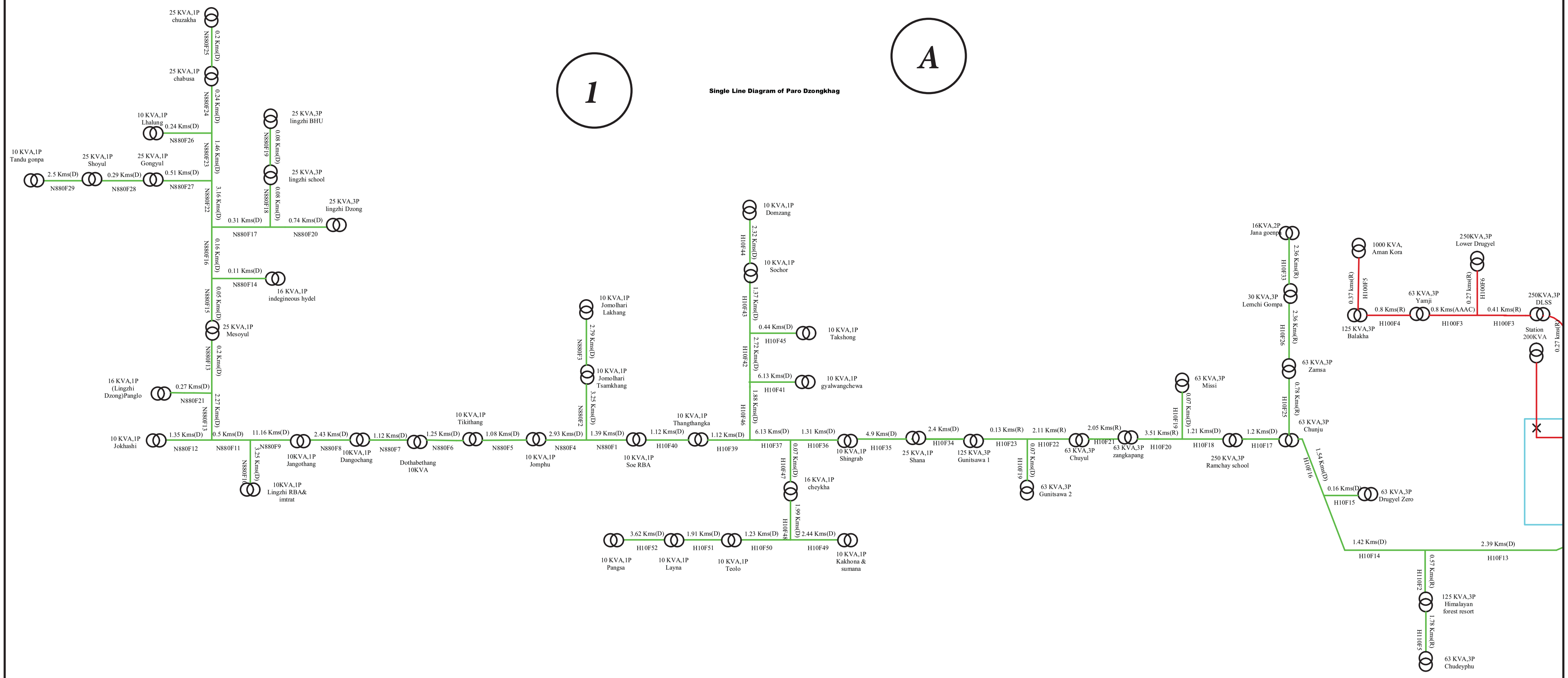
Sl. No.	Source Substation	Feeder ID	Feeder Name	Type of Conductor	Line Length (km)
1	33/11 KV Jangsa Substation	H60	11kV Dotey feeder	Over head	29.38
		H21	11kV lower Jangsa fdr	Over head	7.58
				Under ground	0.13
		H27	11kV NSD fdr	Under ground	0.47
			11kV Tshendona feeder	Over head	9.99
			Jangsa station fdr.	Under ground	0.04
			33kV Olathang to Tsongdue and then to Jangsa Feeder	Over head	0
2	33/11kV Jitsiphu Substation	H10	11kV Balakha fdr.	Over head	2.84
		H12	11kV Taktshang fdr	Over head	5.75
				Under ground	0.18
		H11	11kV Kichu feeder	Over head	8.48
				Under ground	1.16
		H24	11kV Drugyel Dzong fdr	Over head	3.22
				Under ground	0.7
			Jitsiphu Station Fdr.	Under ground	0.04
3	33/11kV Shaba substation	H15	11kV RBA fdr	Over head	14.45
			11kv Shab Bara Fdr.	Over head	3.14
		H14	11kV Hephu fdr	Over head	18.34
		H13	11kV Drugidingkha fdr.	Over head	17.25
				Under ground	0.31
			Shaba station feeder	Under ground	0.04
4	33/11kV Tshongdue substation	H40	11kV Airport fdr	Over head	8.54
				Under ground	0.68
		H60	11kV TA-Dzong fdr.	Over head	9.01
				Under ground	0.67
		H50	11kV Town fdr.	Over head	10.24
				Under ground	0.93
			Tshongdue Station Fdr.	Under ground	0.04
5	66/33/11kV Pangbesa substation		11kV dinning fdr	Under ground	1.33
			11kV school fdr.	Under ground	1.85
6	33kV feeders out going feeders	H	33kV O/G feeder No. III(from Jemina)	Over head	24.61
				Under ground	0.13
		H10	33kV O/G feeder No. I (Drugyel)	Over head	121.37
				Under ground	0.36
		H20	33kV O/G feeder III (Shaba)	Over head	60.73
				Under ground	0.33
		H90	33kV O/G feeder No. IV(Jangsa)	Over head	3.86
				Under ground	0.65
			33kV line from Jangsa towards Drugyel	Over head	5.44
			33kV Olathang station feeder	Under ground	0.05

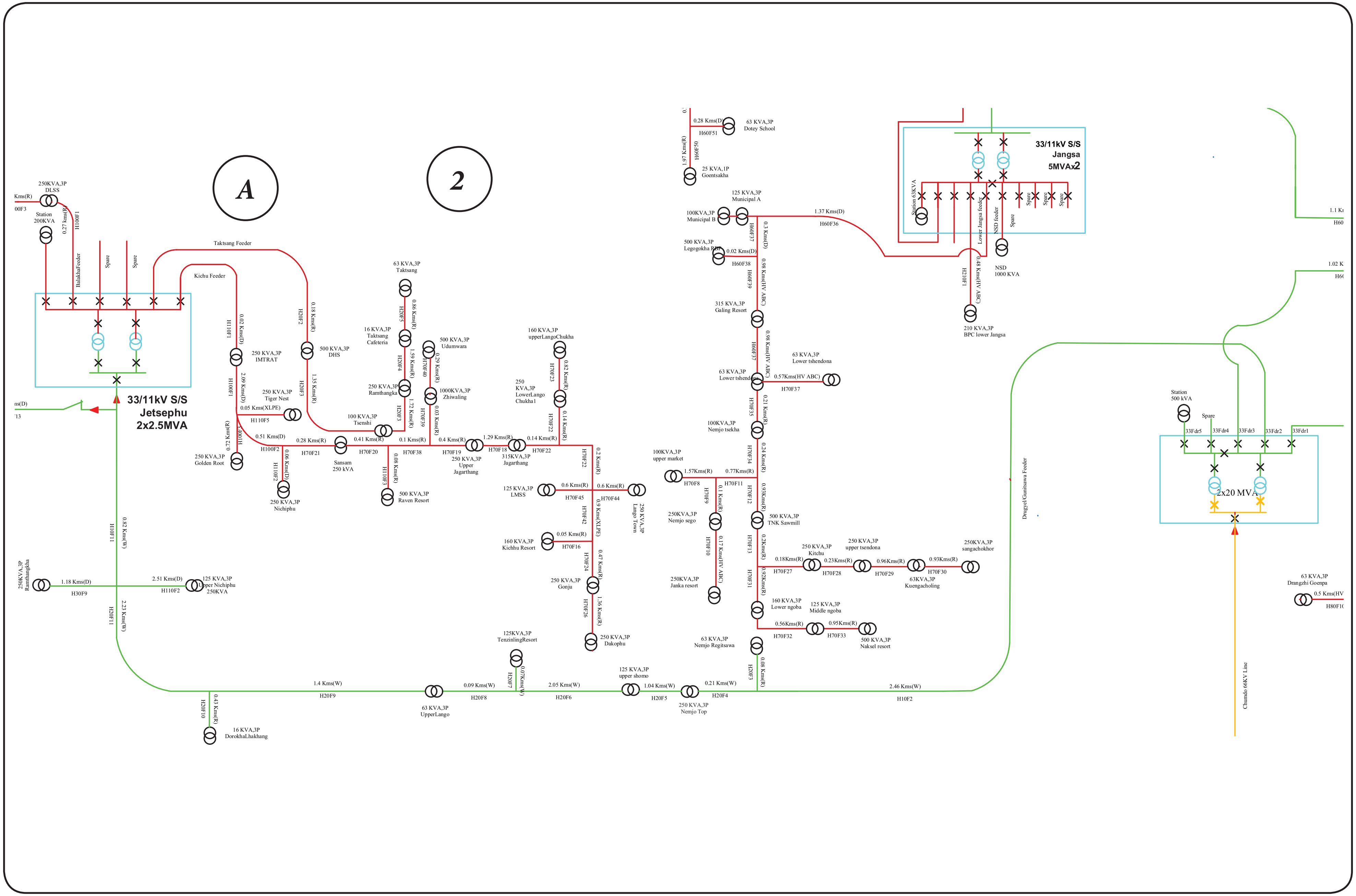

Legends
DistributionTransformer
33 KV Line
11 KV Line
Power Transformer
ARCB
LBS
Four Pole(4P)



A
Legends
DistributionTransformer
33 KV Line
11 KV Line
Power Transformer
ARCB
LBS
Four Pole(4P)
Single Line Diagram of Paro Dzongkhag
1
2
3
33/11kV S/S
Jetsephu
2x2.5MVA
33/11kV S/S
Jangsa
5MVAx2

Single Line Diagram of Paro Dzongkhag





A
2
33/11kV S/S Jetsephu 2x2.5MVA
33/11kV S/S Jangsa 5MVAx2
2x20 MVA
Taktsang Feeder
Kichu Feeder
Balakha Feeder
Lower Jangsa feeder
NSD feeder
Drugyel/Gumitsawa Feeder
Chumdo 66KV Line
Station 200KVA
250KVA,3P DLSS
250 KVA,3P IMTRAT
250 KVA,3P Tiger Nest
250 KVA,3P Golden Root
250 KVA,3P Nichiphu
500 KVA,3P DHS
63 KVA,3P Taktsang
16 KVA,3P Taktsang Cafeteria
250 KVA,3P Ramthangka
100 KVA,3P Tsenshi
Sansam 250 kVA
500 KVA,3P Raven Resort
500 KVA,3P Udumwara
1000KVA,3P Zhiwaling
250 KVA,3P Upper Jagarthang
315KVA,3P Jagarthang
160 KVA,3P upperLangoChukha
250 KVA,3P LowerLango Chukha1
125 KVA,3P LMSS
250 KVA,3P Lango Town
160 KVA,3P Kichhu Resort
250 KVA,3P Gonju
250 KVA,3P Dakophu
125KVA,3P TenzinlingResort
63 KVA,3P UpperLango
125 KVA,3P upper shomo
250 KVA,3P Nemjo Top
16 KVA,3P DorokhaLhakhang
250KVA,3P Ramthangkha
125 KVA,3P Upper Nichiphu 250KVA
100KVA,3P upper market
250KVA,3P Nemjo sego
250KVA,3P Janka resort
100KVA,3P Nemjo tsekha
63 KVA,3P Lower tshendona
315 KVA,3P Galing Resort
500 KVA,3P Legogokha
100KVA,3P Municipal B
125 KVA,3P Municipal A
25 KVA,1P Goentsakha
63 KVA,3P Dotey School
500 KVA,3P TNK Sawmill
250 KVA,3P Kitchu
250 KVA,3P upper tsendona
63KVA,3P Kuengacholing
250KVA,3P sangachokhor
160 KVA,3P Lower ngoba
125 KVA,3P Middle ngoba
500 KVA,3P Naksel resort
63 KVA,3P Nemjo Regitsawa
210 KVA,3P BPC lower Jangsa
NSD 1000 KVA
Station 63KVA
Station 500 kVA
63 KVA,3P Drangzhi Goenpa
33Fdr1
33Fdr2
33Fdr3
33Fdr4
33Fdr5
Spare
H10F2
H20F3
H20F4
H20F5
H20F6
H20F7
H20F8
H20F9
H20F10
H10F11
H20F11
H30F9
H110F2
H100F1
H110F1
H110F5
H100F2
H70F20
H70F21
H70F38
H70F19
H70F18
H70F22
H70F23
H70F45
H70F44
H70F42
H70F16
H70F24
H70F26
H60F36
H60F37
H60F38
H60F39
H70F37
H70F35
H70F34
H70F11
H70F8
H70F9
H70F10
H70F12
H70F13
H70F27
H70F28
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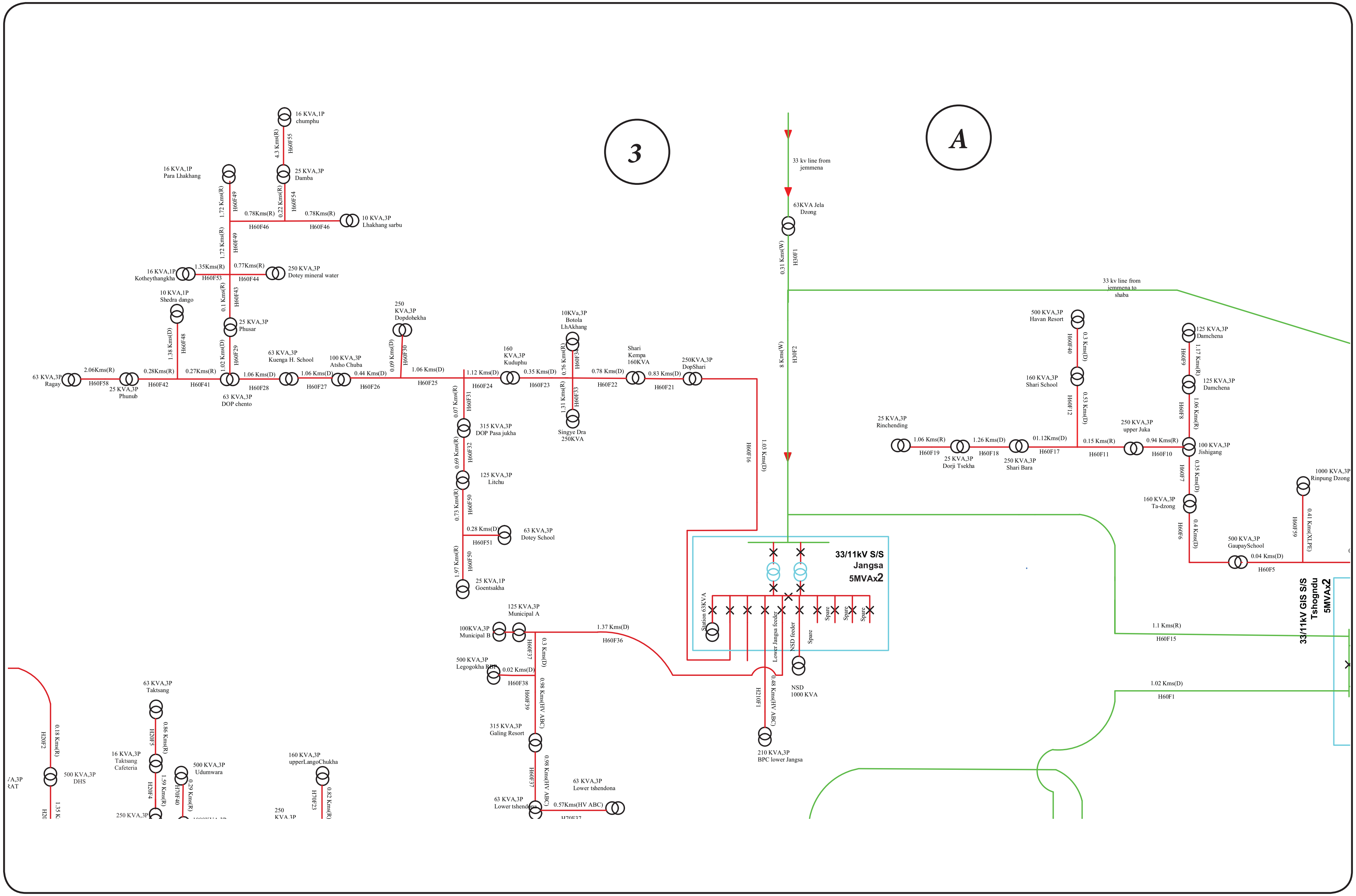
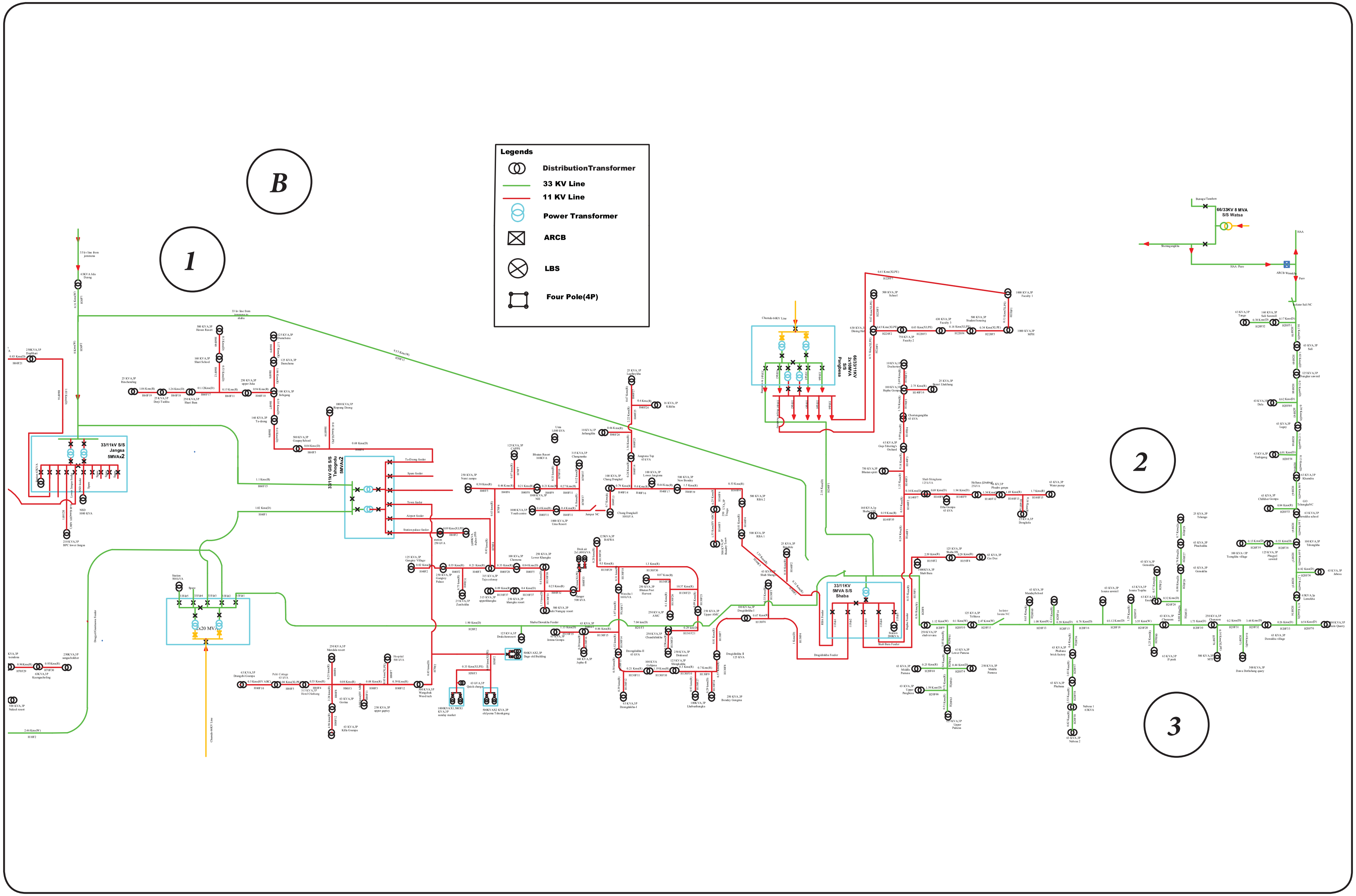
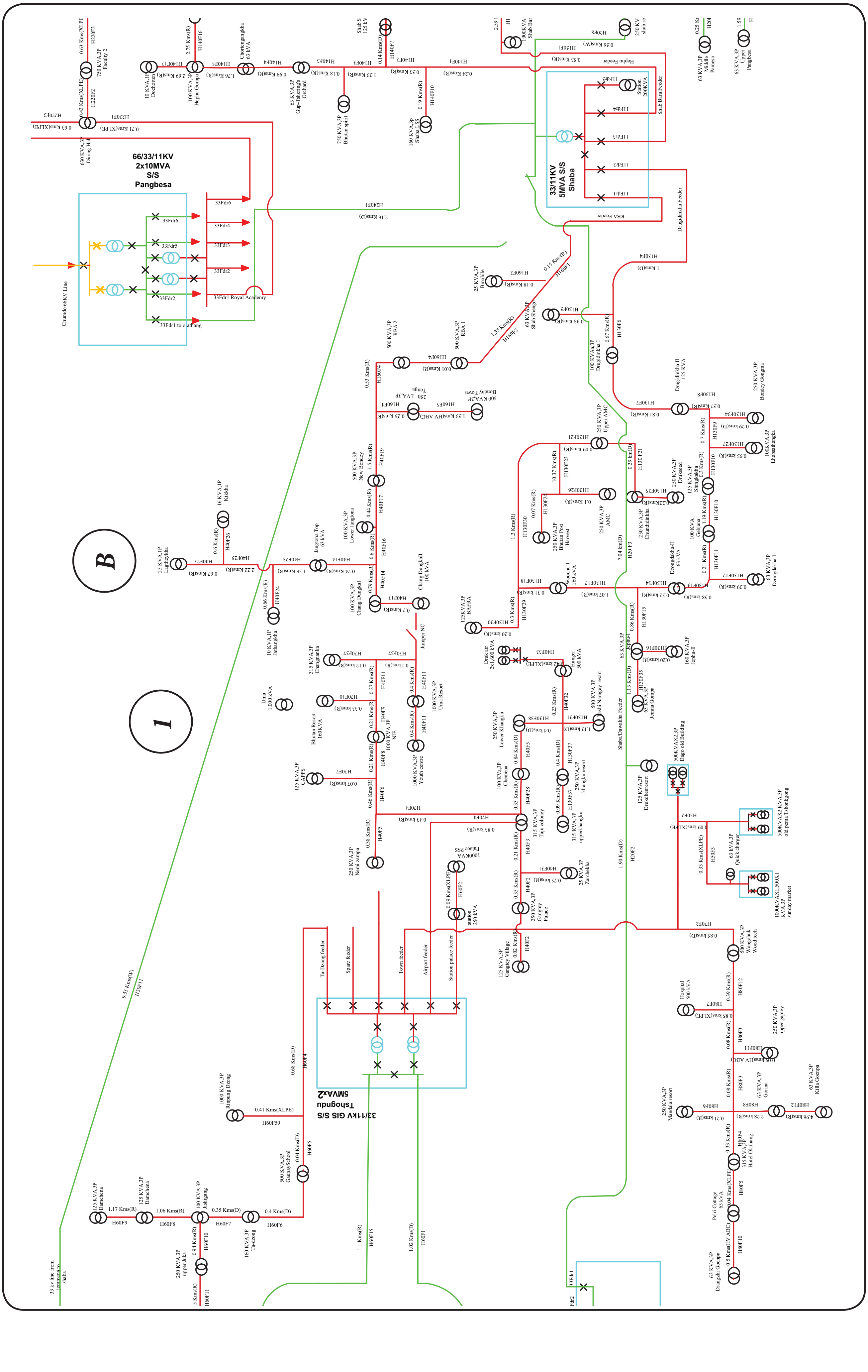
H70F31
H70F32
H70F33
H60F50
H60F51
H210F1
H80F1



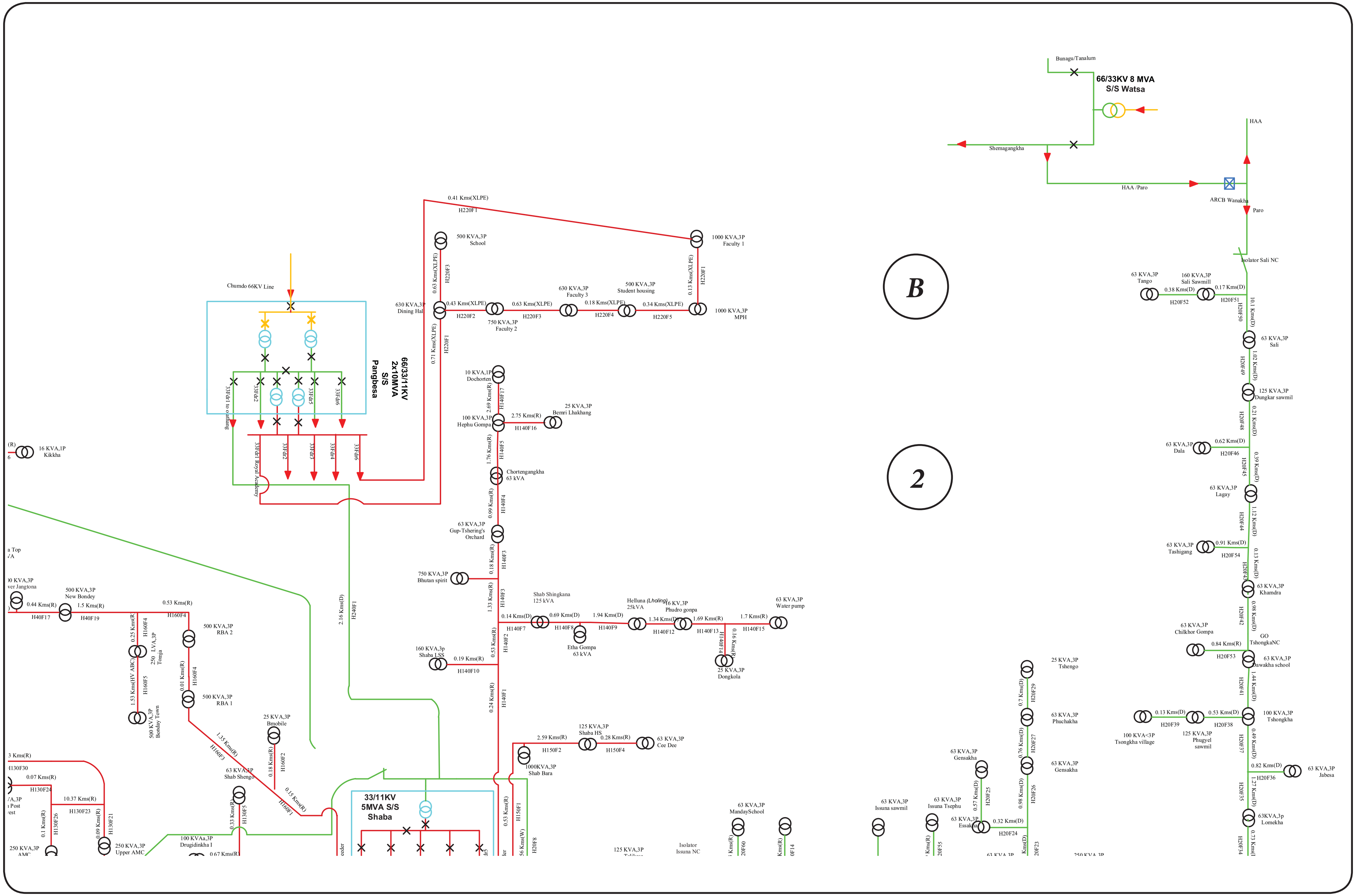
A
3
33/11kV S/S
Jangsa
5MVAx2
33/11kV GIS S/S
Tshogndu
5MVAx2
33 kv line from jemmena
63KVA Jela Dzong
33 kv line from jemmena to shaba
Station 63KVA
Lower Jangsa feeder
NSD feeder
Spare
NSD 1000 KVA
210 KVA,3P BPC lower Jangsa
250KVA,3P DopShari
Shari Kempa 160KVA
10KVa,3P Botola LhAkhang
Singye Dra 250KVA
160 KVA,3P Kuduphu
315 KVA,3P DOP Pasa jukha
125 KVA,3P Litchu
63 KVA,3P Dotey School
25 KVA,1P Goentsakha
250 KVA,3P Dopdohekha
100 KVA,3P Atsho Chuba
63 KVA,3P Kuenga H. School
63 KVA,3P DOP chento
25 KVA,3P Phusar
25 KVA,3P Phunub
63 KVA,3P Ragay
10 KVA,1P Shedra dango
16 KVA,1P Kotheythangkha
250 KVA,3P Dotey mineral water
16 KVA,1P Para Lhakhang
25 KVA,3P Damba
16 KVA,1P chumphu
10 KVA,3P Lhakhang sarbu
125 KVA,3P Municipal A
100KVA,3P Municipal B
500 KVA,3P Legogokha RBP
315 KVA,3P Galing Resort
63 KVA,3P Lower tshendona
500 KVA,3P Havan Resort
160 KVA,3P Shari School
25 KVA,3P Rinchending
25 KVA,3P Dorji Tsekha
250 KVA,3P Shari Bara
250 KVA,3P upper Juka
100 KVA,3P Jishigang
125 KVA,3P Damchena
160 KVA,3P Ta-dzong
500 KVA,3P GaupaySchool
1000 KVA,3P Rinpung Dzong
63 KVA,3P Taktsang
16 KVA,3P Taktsang Cafeteria
500 KVA,3P Udumwara
500 KVA,3P DHS
160 KVA,3P upperLangoChukha



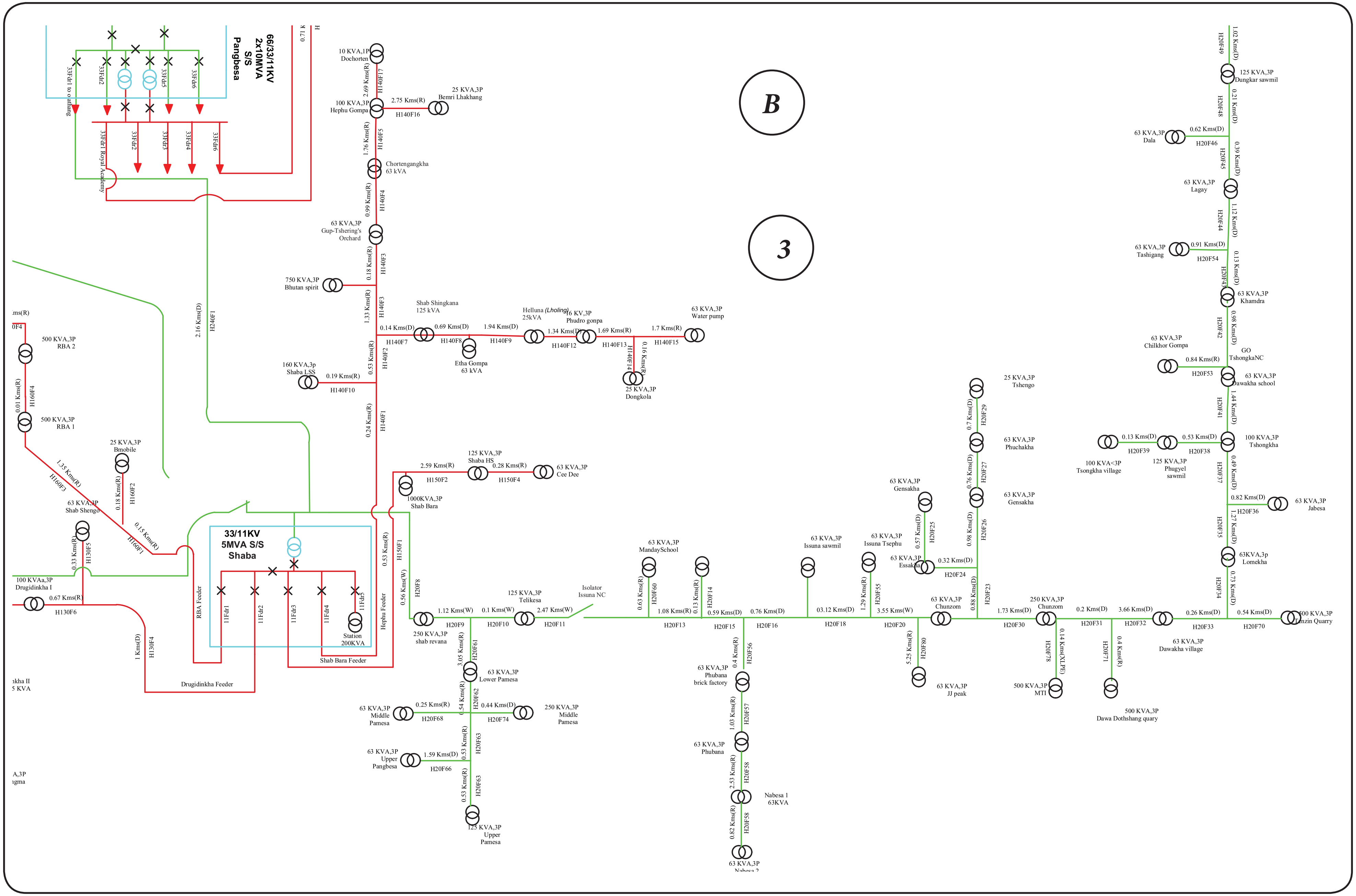
Legends
DistributionTransformer
33 KV Line
11 KV Line
Power Transformer
ARCB
LBS
Four Pole(4P)
B
1
2
3
33/11kV S/S Jangsa 5MVAx2
33/11kV GIS S/S Tshogndu 5MVAx2
66/33/11KV 2x10MVA S/S Pangbesa
33/11KV 5MVA S/S Shaba
66/33KV 8 MVA S/S Watsa



66/33/11KV
2x10MVA
S/S
Pangbesa
33/11KV
5MVA S/S
Shaba
33/11KV GIS S/S
Tshogndu
5MVAx2
Chumdo 66KV Line
33Fdr1 Royal Academy
33Fdr2
33Fdr3
33Fdr4
33Fdr5
33Fdr6
Hepha Feeder
Shab Bara Feeder
Drugidaikha Feeder
RBA Feeder
Shaba/Dawakha Feeder
Ta-Dzong feeder
Spare feeder
Town feeder
Airport feeder
Station palace feeder
33 kv line from
Jemena to
shaba
9.53 Kms(W)
H30F11
B
1



66/33KV 8 MVA
S/S Watsa
Bunagu/Tanalum
Shemagangkha
HAA /Paro
ARCB Wanakha
HAA
Paro
Isolator Sali NC
B
2
66/33/11KV
2x10MVA
S/S
Pangbesa
Chumdo 66KV Line
33Fdr1 Royal Academy
33Fdr2
33Fdr3
33Fdr4
33Fdr6
33/11KV
5MVA S/S
Shaba
1000 KVA,3P Faculty 1
1000 KVA,3P MPH
500 KVA,3P School
630 KVA,3P Dining Hal
750 KVA,3P Faculty 2
630 KVA,3P Faculty 3
500 KVA,3P Student housing
10 KVA,1P Dochorten
100 KVA,3P Hephu Gompa
25 KVA,3P Bemri Lhakhang
Chortengangkha 63 kVA
63 KVA,3P Gup-Tshering's Orchard
750 KVA,3P Bhutan spirit
160 KVA,3p Shaba LSS
Shab Shingkana 125 kVA
Etha Gompa 63 kVA
Helluna (Lholing) 25kVA
16 KV,3P Phudro gonpa
25 KVA,3P Dongkola
63 KVA,3P Water pump
125 KVA,3P Shaba HS
63 KVA,3P Cee Dee
1000KVA,3P Shab Bara
16 KVA,1P Kikkha
500 KVA,3P New Bondey
500 KVA,3P RBA 2
500 KVA,3P RBA 1
250 LVA,3P Tonga
500 KVA,3P Bonday Town
25 KVA,3P Bmobile
63 KVA,3P Shab Shengo
250 KVA,3P Upper AMC
100 KVAa,3P Drugidinkha I
63 KVA,3P Tango
160 KVA,3P Sali Sawmill
63 KVA,3P Sali
125 KVA,3P Dungkar sawmil
63 KVA,3P Dala
63 KVA,3P Lagay
63 KVA,3P Tashigang
63 KVA,3P Khamdra
63 KVA,3P Chilkhor Gompa
GO TshongkaNC
63 KVA,3P Jawakha school
100 KVA,3P Tshongkha
100 KVA<3P Tsongkha village
125 KVA,3P Phugyel sawmil
63 KVA,3P Jabesa
63KVA,3p Lomekha
25 KVA,3P Tshengo
63 KVA,3P Phuchakha
63 KVA,3P Gensakha
63 KVA,3P Issuna sawmil
63 KVA,3P Issuna Tsephu
63 KVA,3P Essakha
63 KVA,3P MandaySchool
Isolator Issuna NC


B
3
66/33/11KV
2x10MVA
S/S
Pangbesa
33/11KV
5MVA S/S
Shaba
33Fdr1 Royal Academy
33Fdr2
33Fdr3
33Fdr4
33Fdr6
RBA Feeder
Drugidinkha Feeder
Shab Bara Feeder
Hephu Feeder
H240F1
2.16 Kms(D)
Station
200KVA
10 KVA,1P
Dochorten
100 KVA,3P
Hephu Gompa
25 KVA,3P
Bemri Lhakhang
Chortengangkha
63 kVA
63 KVA,3P
Gup-Tshering's
Orchard
750 KVA,3P
Bhutan spirit
160 KVA,3p
Shaba LSS
Shab Shingkana
125 kVA
Etha Gompa
63 kVA
Helluna (Lholing)
25kVA
16 KV,3P
Phudro gonpa
63 KVA,3P
Water pump
25 KVA,3P
Dongkola
125 KVA,3P
Shaba HS
63 KVA,3P
Cee Dee
1000KVA,3P
Shab Bara
500 KVA,3P
RBA 2
500 KVA,3P
RBA 1
25 KVA,3P
Bmobile
63 KVA,3P
Shab Shengo
100 KVAa,3P
Drugidinkha I
250 KVA,3P
shab revana
125 KVA,3P
Telikesa
Isolator
Issuna NC
63 KVA,3P
Lower Pamesa
63 KVA,3P
Middle
Pamesa
250 KVA,3P
Middle
Pamesa
63 KVA,3P
Upper
Pangbesa
125 KVA,3P
Upper
Pamesa
63 KVA,3P
MandaySchool
63 KVA,3P
Phubana
brick factory
63 KVA,3P
Phubana
Nabesa 1
63KVA
63 KVA,3P
Issuna sawmil
63 KVA,3P
Issuna Tsephu
63 KVA,3P
Essakha
63 KVA,3P
Gensakha
63 KVA,3P
Chunzom
63 KVA,3P
JJ peak
25 KVA,3P
Tshengo
63 KVA,3P
Phuchakha
63 KVA,3P
Gensakha
250 KVA,3P
Chunzom
500 KVA,3P
MTI
500 KVA,3P
Dawa Dothshang quary
63 KVA,3P
Dawakha village
500 KVA,3P
Tenzin Quarry
63KVA,3p
Lomekha
63 KVA,3P
Jabesa
100 KVA<3P
Tsongkha village
125 KVA,3P
Phugyel
sawmil
100 KVA,3P
Tshongkha
63 KVA,3P
Dawakha school
GO
TshongkaNC
63 KVA,3P
Chilkhor Gompa
63 KVA,3P
Khamdra
63 KVA,3P
Tashigang
63 KVA,3P
Lagay
63 KVA,3P
Dala
125 KVA,3P
Dungkar sawmil

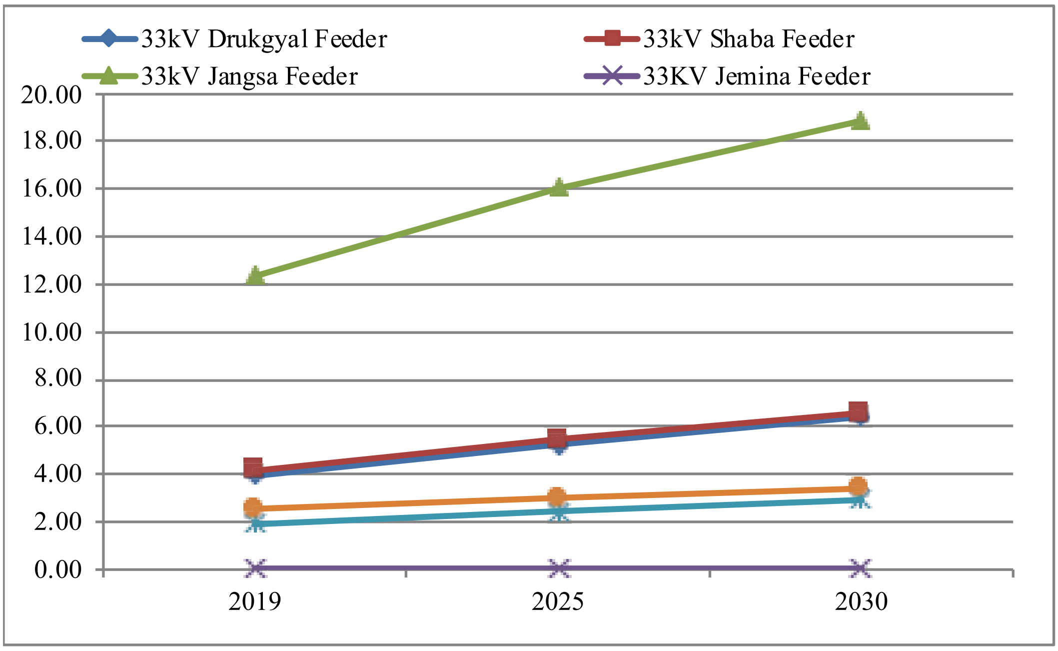
Annexure-2: IS 2026, IEC 60076 (Technical parameters for Distribution Lines and Transformers)

Sl. No.	Parameter	Requirement
1	Applicable standard	IS 2026, IEC 60076
2	Type	Oil filled[1] / two winding
3	Winding material	Copper
4	Core Material	CRGO silicon steel/Amorphous Metal
5	Cooling	Oil natural air natural (ONAN)
6	Terminations	
	· Primary	Outdoor Bushing or cable box[2]
	· Secondary	Outdoor Bushing or Cable box
7	Rated no load voltage	
	· Primary	33 kV or 11 kV
	· Secondary	415/240 V
8	% Impedance	
	10 kVA-24 kVA (1phase/3phase)	3%
	25 kVA-630 kVA	4%
	631 kVA-1250 kVA	5%
9	Vector group	Dyn11
10	Tap changer	
	· Type	Off load
	· Range	+5% to -5%
	· Step value	2.50%
11	Insulation Class (IEC-76)	A
12	Permissible Temperature rise	
	· Maximum winding temperature	55ºC
	· Max. Top oil temperature	50°C
13	Insulation levels	
	· Primary	170 kVp-70 kV/75 kVp-28 kV
	· Secondary	7500 Vp-3000 V

Annexure-3: Load Forecast adopting LRM & TSA

Load forecast for Paro Dzongkhag

Sl. No.	Feeder Name	Forecasted Feeder Load (MW)		
		2019	**2025**	**2030**
1	33kV Drukgyal Feeder	3.94	5.21	6.42
2	33kV Shaba Feeder	4.16	5.48	6.59
3	33kV Jangsa Feeder	12.35	16.08	18.88
4	33kV Wanakha/Dawakha Feeder	Alternative route		
5	33KV Jemina Feeder	0.05	0.05	0.05
6	33kV Shaba Feeder from Jangsa	1.91	2.44	2.93
7	11kV Royal Academy Feeder	2.56	2.98	3.41
	Total load (MW)	**24.96**	**32.23**	**38.27**



Load forecast methodolgy

1. Load Forecast

1.1 Type of Load Forecast and Power System Planning

One of the power system planning element is the load forecast. Although, there are no documented standards specifying the type of planning however, the power system planning can be short-term planning (STP) (less than one year), medium-term planning (MTP) (1-3 years) and long-term planning (LTP) (3-10 years and even higher). It is necessary to predict the power requirement for a specified time-horizon which is referred to as load (power) forecasting based on the historical consumption pattern for better planning and optimizing the available resources. Analogy to power system planning, the load forecast can be also short-term load forecasting (STLF), medium-term load forecasting (MTLF) and long-term load forecasting (LTLF) and accordingly the distribution network expansion programs are proposed[1] for distributing the electricity.

There are number of driving factors which are listed below affecting the forecasted load.

a) Time
   - Hours of the day (day or night)
   - Day of the week (weekdays or weekend)
   - Time of the year (winter or summer season)
b) Weather conditions (temperature and humidity)
c) Type of customers (residential, commercial, industries etc.)
d) Population
e) Economic indicators (per capita income, Gross Domestic Product (GDP) etc.)
f) Prices of the electricity

As the DSMP is being developed for 10-year period, the load forecast has to be done for same time horizon. Therefore, some of the driving factors as listed above which affects the LTLF may not impact the accuracy as daily, weekly and monthly time factors and weather conditions will have minimum contribution to the load variance.

1.2 Methods of Load (LTLF) Forecast

The LTLF methods are generally the trend analysis or time series analysis, economic modelling, end-use analysis and hybrid analysis. As the DSMP is for 10-year period, the methods of LTFL is being outlined for forecasting the load[1].

1.2.1 Trend Analysis

In the trend analysis, the historical data (power) is used to forecast the load. The details on load forecast adopting power consumption trend is reflected in **Section 1.3.** Typical load forecast is as shown in **Figure 1.**

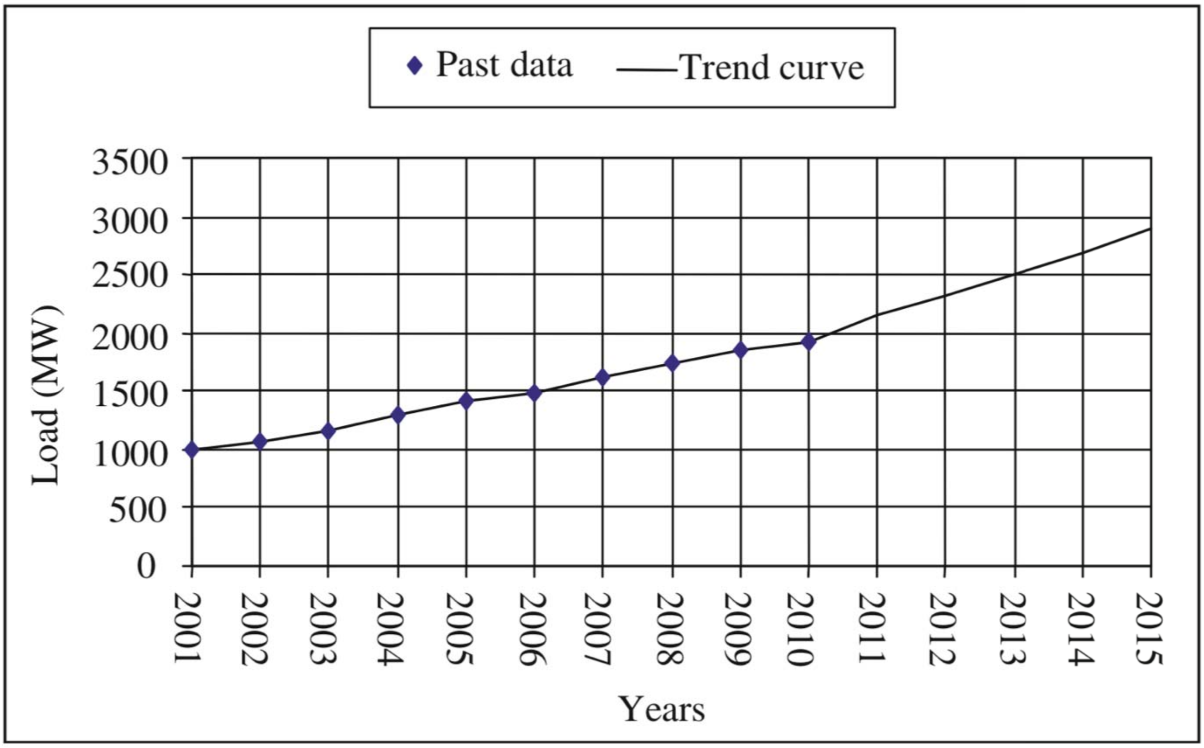


Figure 1: Typical trend curve[1]

1.2.2 Economic Modelling

In this method, the relationship between the load and the driving parameters are established and accordingly the future values of the driving factors are projected. Although, this approach is widely being used, as most of the data for driving factors are not available and for simplicity the trend analysis is adopted to forecast the load.

1.2.3 End-use Analysis

This approach is exclusively used for residential loads which is forecasted in terms of energy and therefore, it requires some methods to convert the predicted energy consumption to load (power demand). There is uncertainty in the accuracy of the predicted load and is also confined to residential customers. Therefore, end-use analysis approach is not adopted to predict the load.

1.2.4 Hybrid Analysis

Although, the end-use and econometric methods may be simultaneously used to forecast the load, it is not widely used as it has advantages and disadvantages of both the approaches.

1.3 Trend Line Analysis

The LTLF is carried out using the trend analysis approach and accordingly for planning the distribution system network. In order to forecast the load, the peak power demand prior to 2020 was considered and the power requirement trend is obtained. Load requirement is then predicted for next ten-year period (2020-2030) by extrapolating the trend line considering the load of 2019 as a base data. The case study of Punakha Dzongkhag is chosen to get insight of actual load forecast.

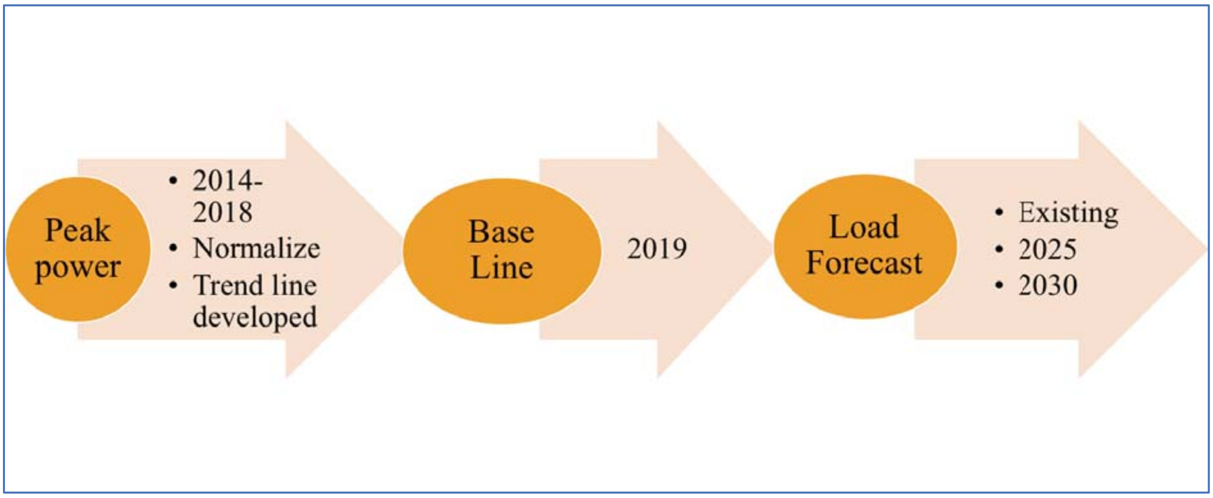


Figure 2: Flow diagram for load forecast

1.3.1 Normalizing the Data

Some of the distribution network do have ring feeders and multiple sources for better reliability and contingency. This in turn has resulted in abnormality in the power consumption data (recordings). Further, in the absence of meters or malfunctioning of the reading equipment or recorded data, some of the feeders have unreliable data for some of the years. Therefore, data is normalized by omitting the outliers or by taking the average of the past data (or average of preceding and future load if a year's data is missing). Such exercise is carried out for all the feeders and substation loads.

Table 1: Actual power data of Punakha Dzongkhag

Sl.No.	Name of Feeder	Consumption Pattern (MW)						
		2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
1	Feeder A	1.85	2.01	0.90	0.22	2.45	2.64	2.63
2	Feeder B	0.48	0.51	4.86	0.50	0.49	0.74	0.72
3	Feeder C	1.35	1.60	1.60	1.80	2.10	1.76	2.40
4	Feeder D	0.96	1.02	1.47	1.48	1.80	2.24	1.89
	Total	**4.64**	**5.14**	**8.83**	**4.00**	**6.84**	**7.37**	**7.64**

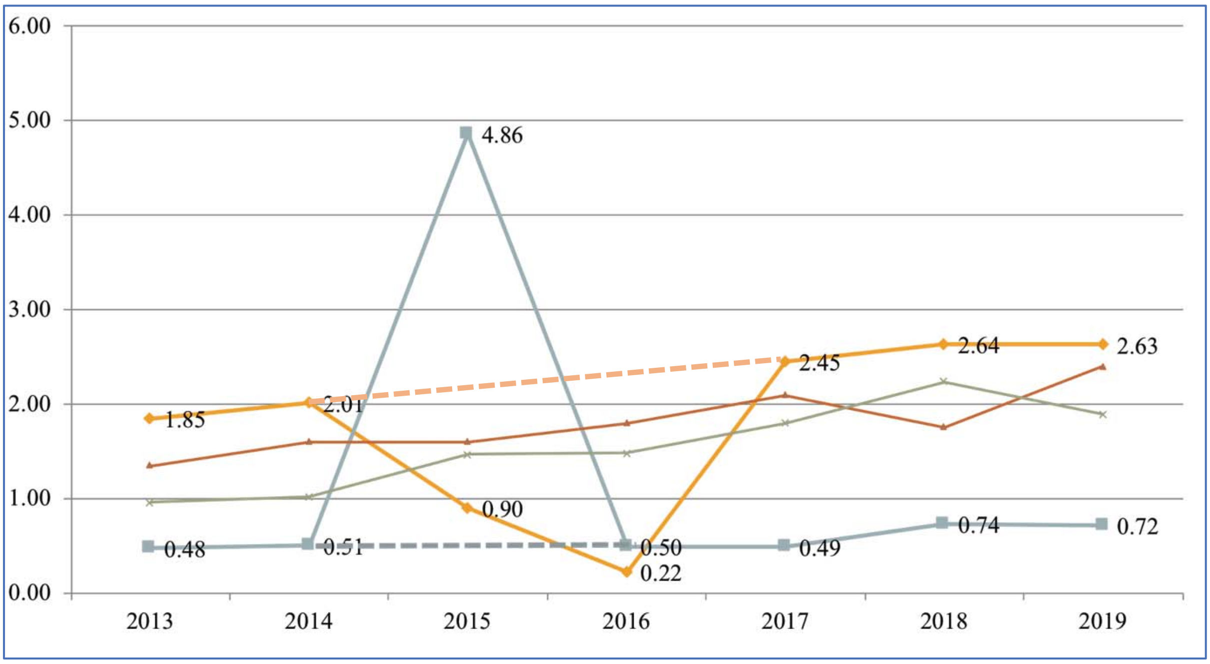


Figure 3: Actual data of Punakha Dzongkhag

$$x = \left(\frac{x_1 + x_2}{2}\right)$$

Where:

x is the normalized data

x_1 and x_2 is the data for two years

Table 2: Normalized power data of Punakha Dzongkhag

Sl.No.	Name of Feeder	Consumption Pattern (MW)						
		2013	2014	2015	2016	2017	2018	2019
1	Feeder A	1.85	2.01	1.93	1.97	2.45	2.64	2.63
2	Feeder B	0.48	0.51	0.49	0.50	0.49	0.74	0.72
3	Feeder C	1.35	1.60	1.60	1.80	2.10	1.76	2.40
4	Feeder D	0.96	1.02	1.47	1.48	1.80	2.24	1.89
	Total	**4.64**	**5.14**	**8.83**	**4.00**	**6.84**	**7.37**	**7.64**

1.3.2 Trend Line and Load Forecast

Based on the power data, the trend line is added to portray the power consumption pattern which gets generated as per the linear regression equation[1]. The trend line added is then extrapolated to forecast the load for next ten years which is as shown in **Figure 4.**

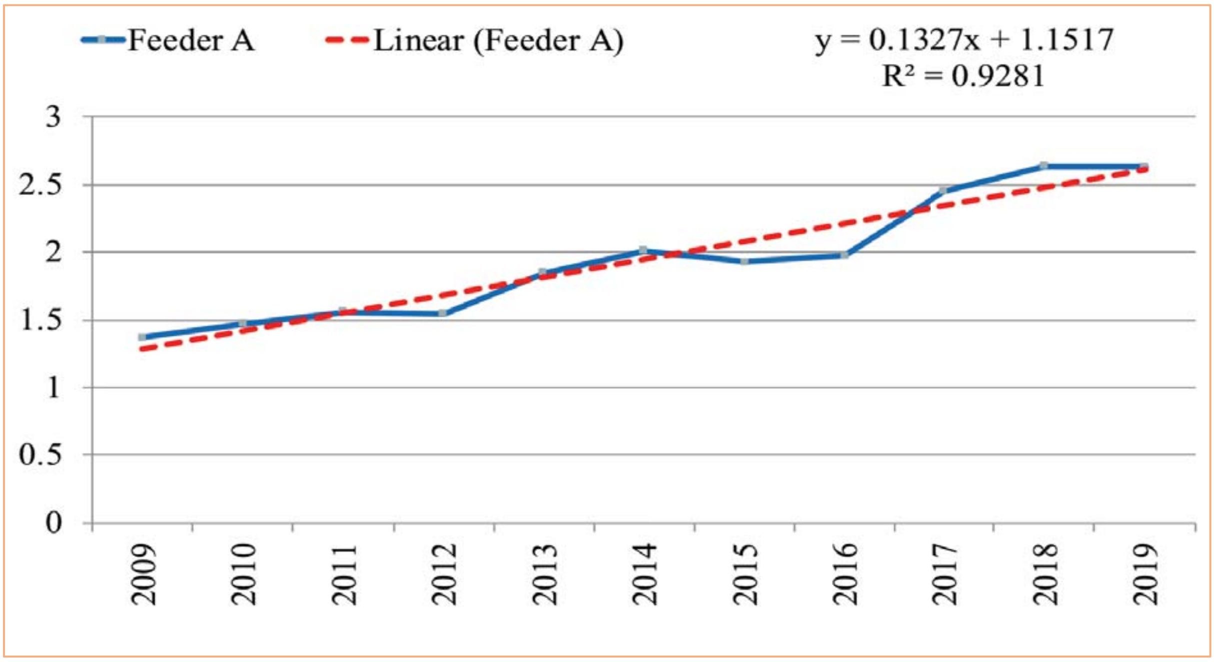


Figure 4: Trend line and load forecast for Punakha Dzongkhag

The trend line equation is given by[2]:

$y = ax + b$

$Where$:

y is the dependent variable or forecasted load
a is the slope which is the average change in y for every increment of x (increase in year).
It also gives x is the independent variable or time in year
b is the intercept which is the predicted value of y when x is zero (time is zero)

The Pearson correlation coefficient *'r',* which can take values between -1 & 1 corresponds to the linear relationship between variables *x & y*. If the *r* value is either -1 or 1, dependent variable can be perfectly explained by a linear function of the other.

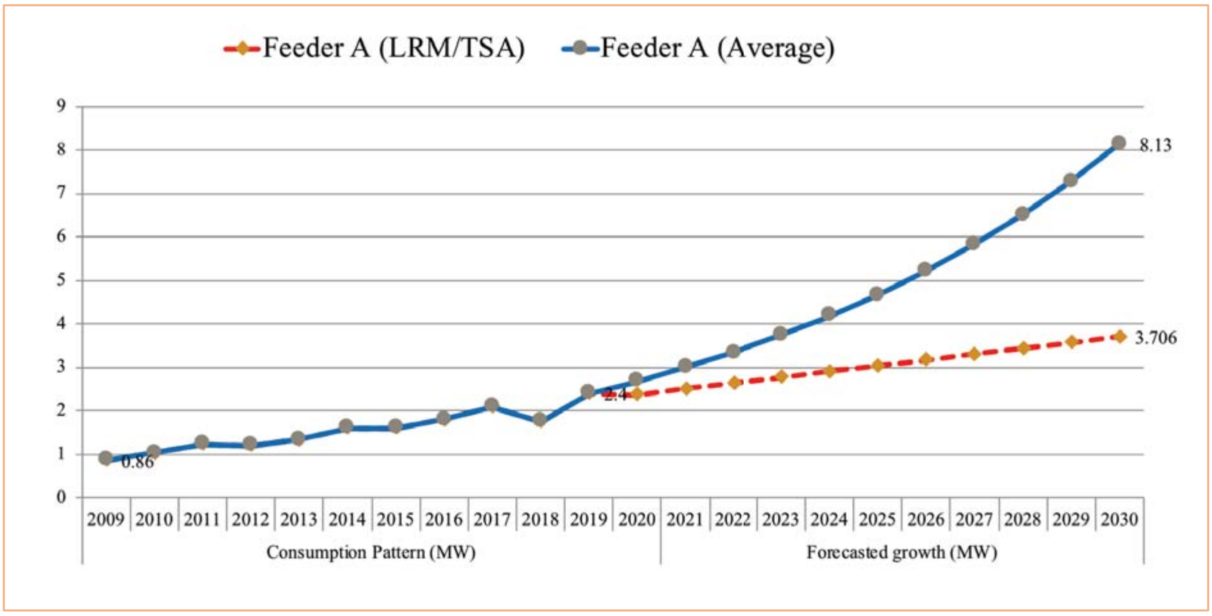


Figure 5: Forecasted load (trend line with red shows the linear regression and one with blue shows the forecast with average method)

2. Electrical Transient Analyser Program (ETAP) –Modelling and Load Flow Analysis

2.1 ETAP Software

"**ETAP** is an analytical engineering solution tool specializing in the simulation, design, monitoring, control, operator training, optimizing, and automating power systems[3]. ETAP's integrated digital platform offers the best comprehensive suite of enterprise solutions."
ETAP software is used in DSMP for modelling/designing, network simulation and to carry out the technical evaluation for distribution power system. The modelled network is fed with the essential data (such as specifications, constraints and parameters for network components) and the simulation results are assessed and analysed. Conclusively, different measures are considered and performed in ETAP for improving the efficiency of a system.

2.2 Load Flow Analysis (ETAP)

Load Flow Analysis (LFA) is a major tool to study and analyse the operation of a power system and determines voltage drops and power flow throughout the electrical system. Using network parameters (Input) for power sources, lines, transformers and connected loads, LFA provides voltages magnitude, real/reactive power, currents, and power losses as a result from the load flow simulation. The study also allows for swing, voltage regulated, and unregulated power sources with multiple power grids and generator connections and the analysis can be performed on both radial and loop systems.

Numerical analysis method such as Adaptive Newton-Raphson, Newton-Raphson, Fast Decoupled, & Accelerated Gauss Seidel methods are accessible in ETAP and can be used for solving the load flow analysis problems.

In this analysis, Adaptive Newton-Raphson method is used for load flow study of distribution networks and the study is carried out under 3-time horizon: present (2019), 2025 and 2030 (forecast load). The results (total generation, loading, system losses, and critical report of load flow) obtained under the scenarios are analysed and corresponding corrective measures are proposed.

2.2.1 Creating the Library

Although, the electrical parameters and specifications are inbuilt, to suit the requirements of the study, the missing electrical parameters are customized by creating a library. The units are set to metric system and accordingly the network is modelled and the relative data for network components such as transformers, line types, power sources and load details are fed in which are detailed as follows:

a) Transmission Cable

- Library-Transmission Line-Phase Conductor-Add-Transmission line library
- In transmission line library: change unit system into Metric, conductor type into ACSR and frequency into 50HZ, and Source name as BPC.
- Click BPC and click edit properties.
- In edit properties add the required conductor parameter by referring the Excel sheet (technical parameters.)
- For AAAC use the source name "Pirelli" and select the required size.

b) UG cable (Since 33kV Al UG Cable is not available):

- Library- Cable- Add-change the source name to BPC and make the necessary changes especially type of conductor to Aluminium and installation into non-magnetic.
- Change insulation type to XLPE.
- Select BPC from the Cable library table and click edit properties
- In edit properties add the required UG cable parameters referring the Excel sheet as shown in Pictures below.

c) Set Loading and Generation Categories.

- Go to Project- Settings- Loading and generation categories
- In Generation Category, set 3 categories as Maximum, Normal and Minimum.
- In AC Load, set 3 categories as 2019, 2025 and 2030.
- Keep the DC Load Empty.

2.2.2 Network Modelling and Load Flow Analysis

a) Draw Distribution Network (SLD).
b) Enter the height=8 and spacing =1.25 in the Transmission line table.
c) Enter the electrical parameters (kW, kVA, kV, etc.) ratings for power sources, transformers, line type, bus kV and loading details.

d) Under the Lump Load, in “Nameplate” edit and enter DT % loading and forecasted % loading details for 2019,2025,2030. Set the load type (80% as constant impedance and 20% as constant KVA) as most of the loads are impedance load.
e) Make sure to run the load flow for each composite network before you continue with other network. This is to avoid numerous errors at the end.
f) After completing the SLD, study case for different load scenarios needs to be created.
g) Switch to “Load Flow Analysis” mode in Mode Toolbar. Go to “Study Case,” select present Case 1 as 2019 and select “Prompt” in “Output Report”
h) Edit the “Load Flow Study Case [Brief Case Symbol].” Go to “Loading” and set to “2019” under Loading Category and set “Normal” under Generation Category. Check the Margins set under Alerts and set “Marginal (±5% for Over and Under Voltage Category)” and set “Critical (±10% for Over and Under Voltage Category)”
i) Close “Load Flow Study Case” and run “Run Load Flow” and save the result as 2019.
j) Similarly, follow step b), c) and d) for 2025 and 2030.
k) To generate the report (SLD drawings) in PDF, go to print preview- set up- change the printer name “Microsoft print to PDF”.

2.3 Consideration/Assumptions made while simulating in ETAP software

a) All Network is considered as balanced system as there is limitation of unbalanced system in ETAP Key.
b) The voltage level of ±10% is given as critical value which is indicated by red colour while simulating and voltage level of ±5% is given as marginal value which is indicated by pink colour while simulating.
c) The typical value of X/R ratio from ETAP inbuilt system is taken for all the power transformers for the simulation.
d) Some of the types of transmission cables /underground cables used in BPC are not available in ETAP library therefore, a new source is created in ETAP library by inserting all the parameters of those unavailable cables/transmission lines.
e) There are three cases created in ETAP simulation depending on the load forecast namely the 2019, 2025 and 2030 where the forecasted loads are given respectively and simulated/analysed accordingly.

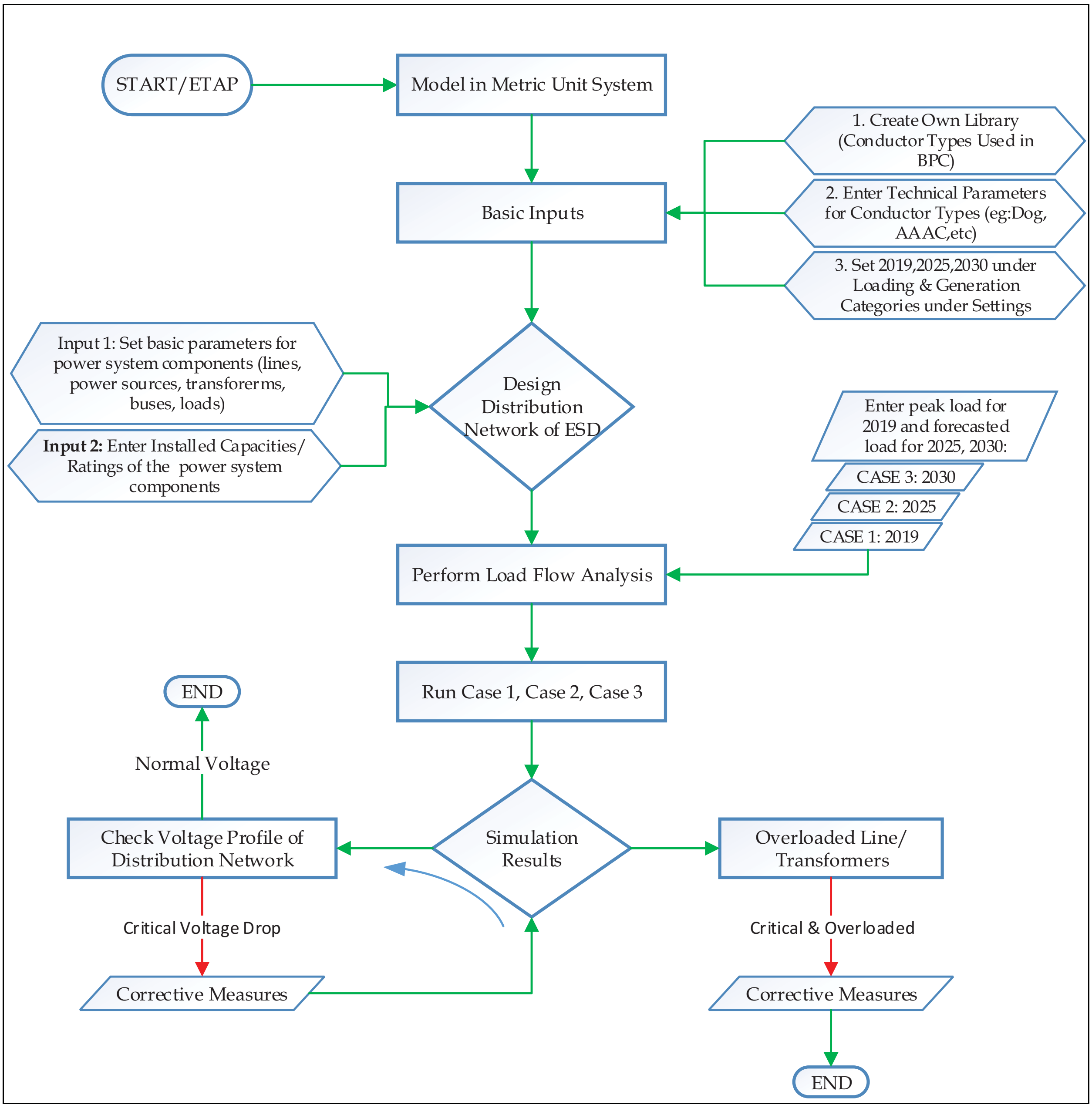


Figure 6: Flow Chart for Network Modelling & Load Flow Analysis (ETAP)

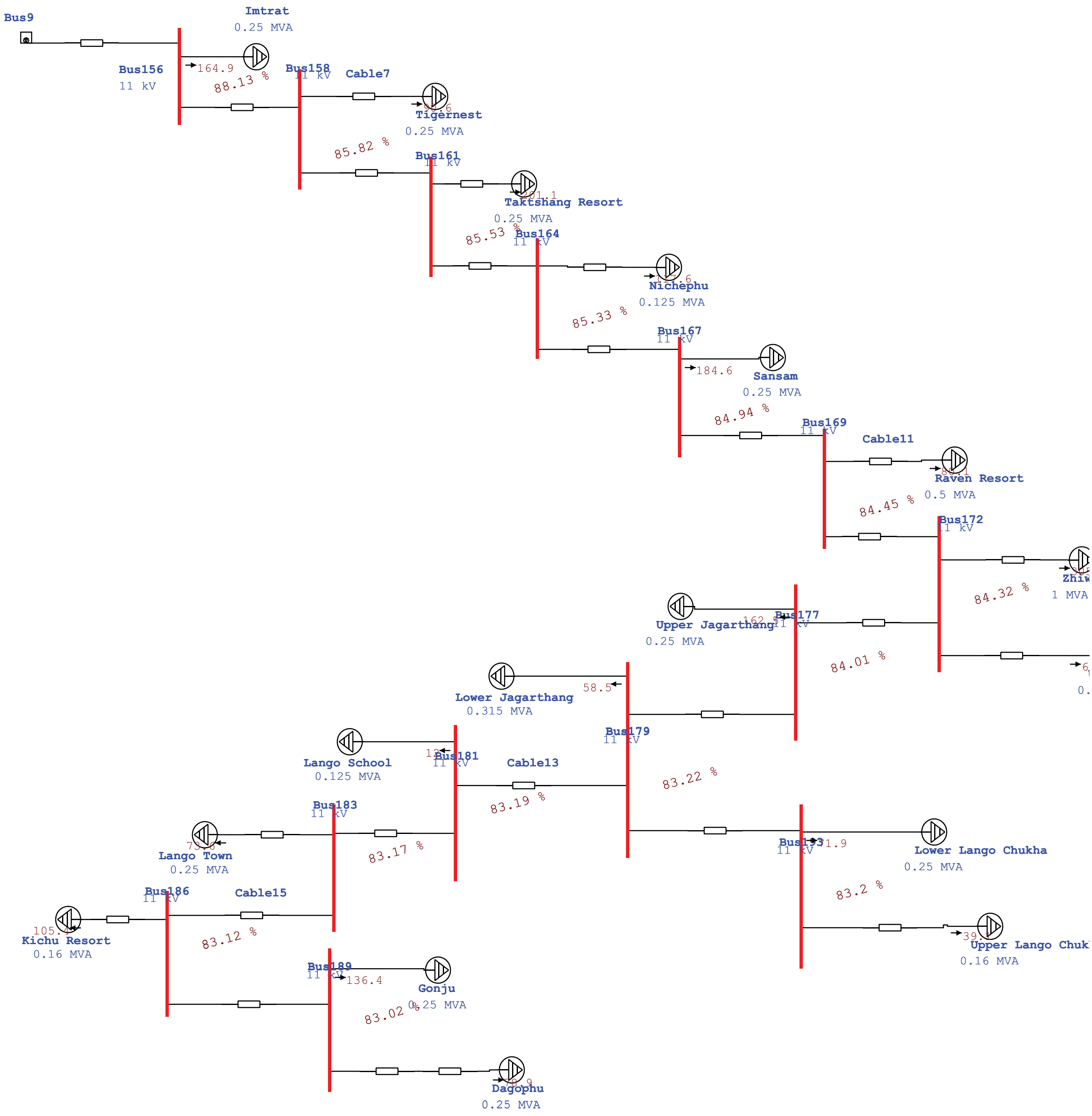
[1]Electric Power System Planning Issues, Algorithms and Solutions by Hossein Seifi Mohammad Sadegh Sepasian

[2]http://sites.utexas.edu/sos/guided/inferential/numeric/bivariate/cor/: dated September 29, 2020

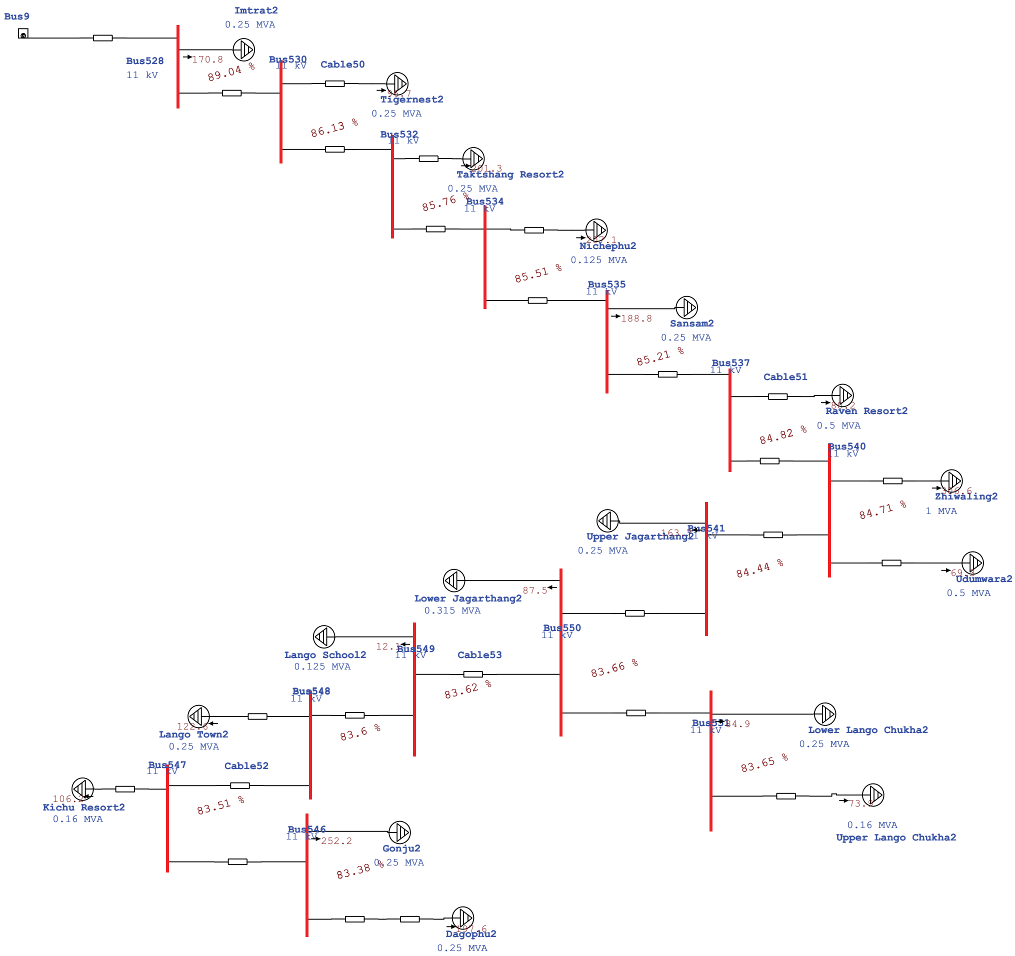
[3]http://www.powerqualityworld.com/2011/05/etap-tutorials-load-flow-analysis.html dated September 30, 2020

Annexure 4: The Simulation Results

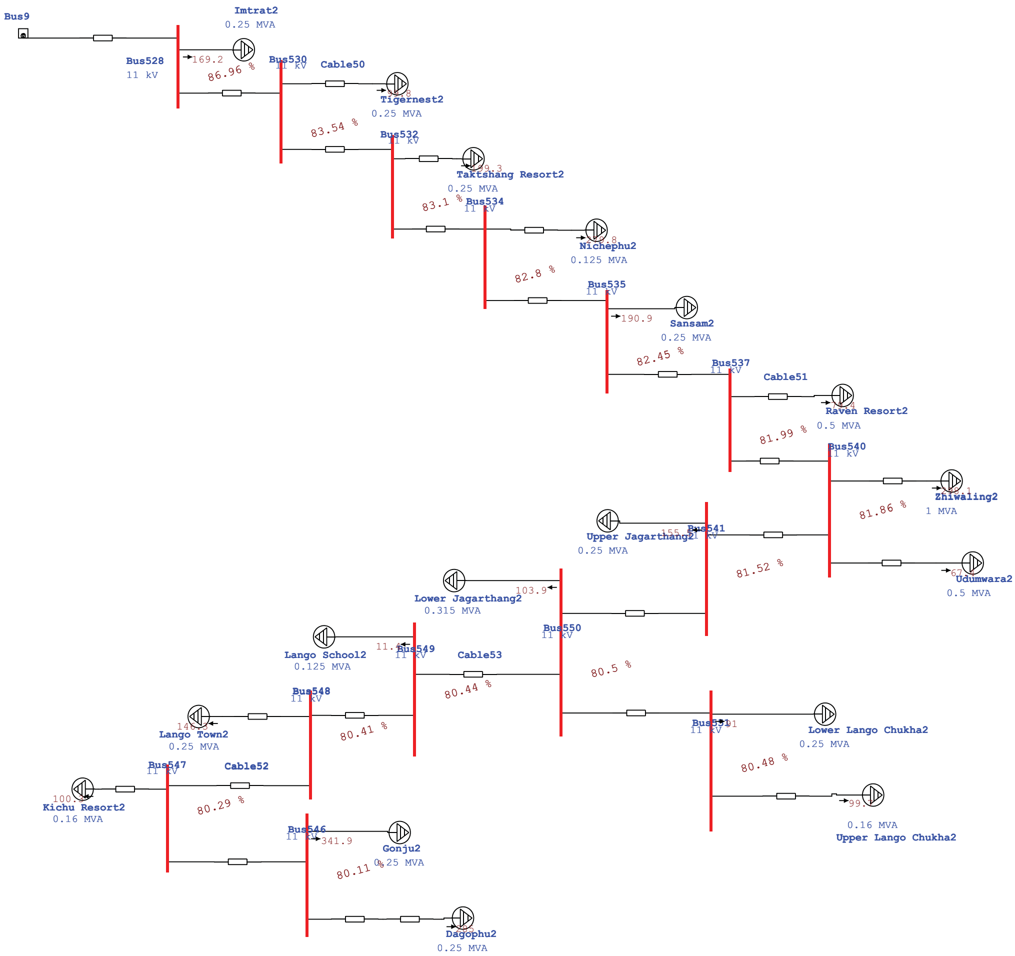
One-Line Diagram - Paro ESD Network=>Ki(H110) (Load Flow Analysis)



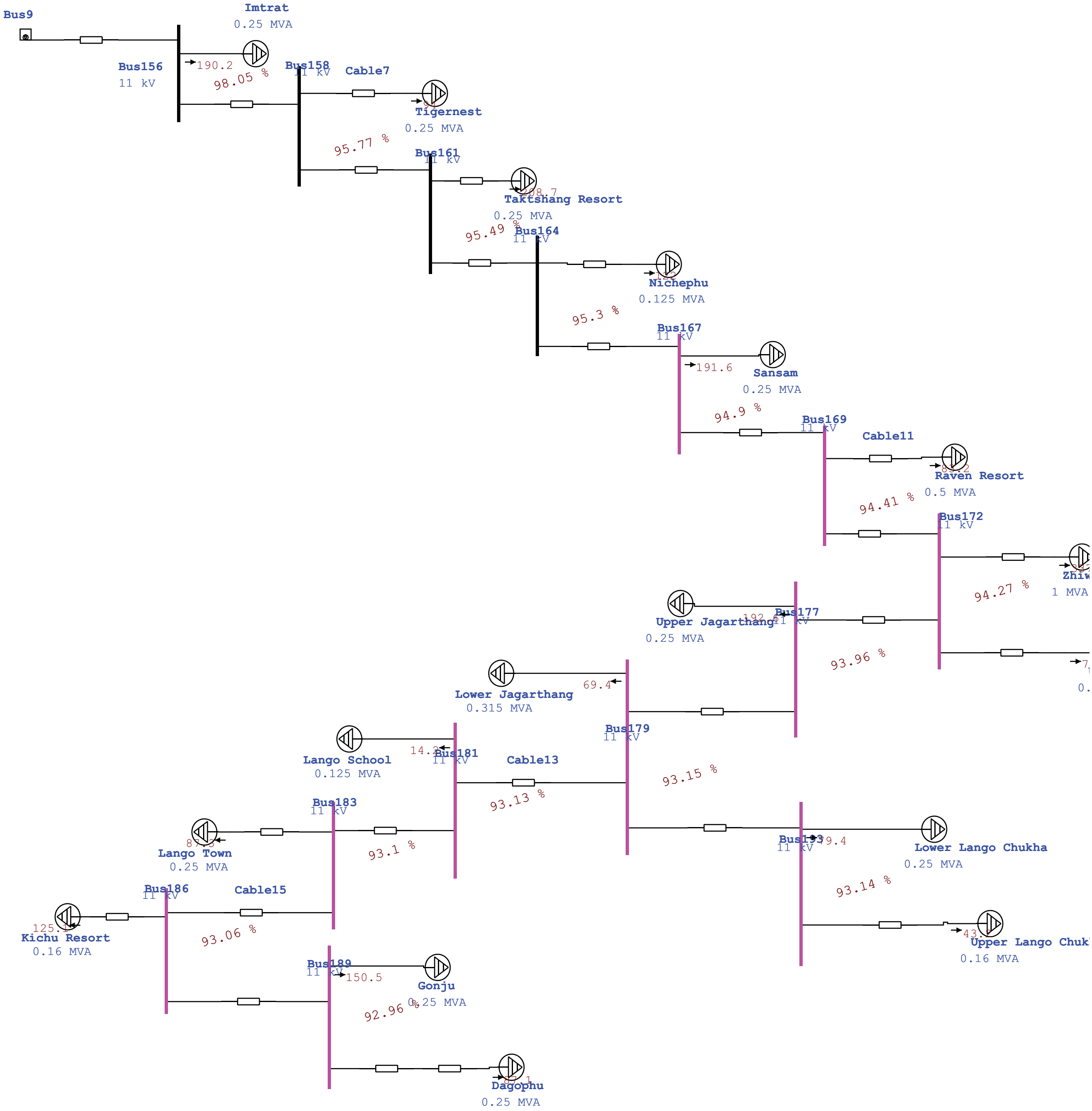
One-Line Diagram - Paro ESD Network=>Ki(H110)2 (Load Flow Analysis)



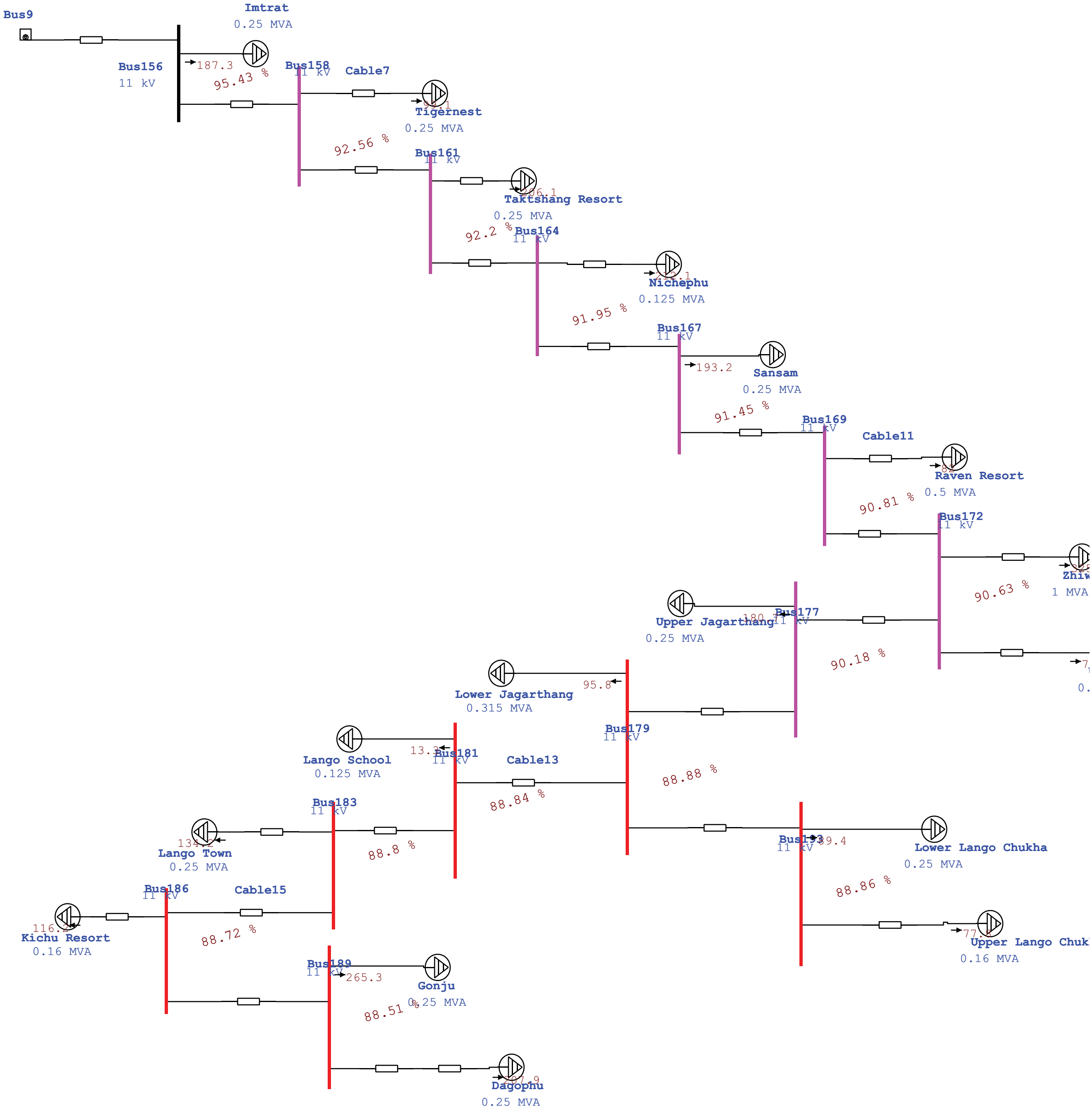
One-Line Diagram - Paro ESD Network=>Ki(H110)2 (Load Flow Analysis)



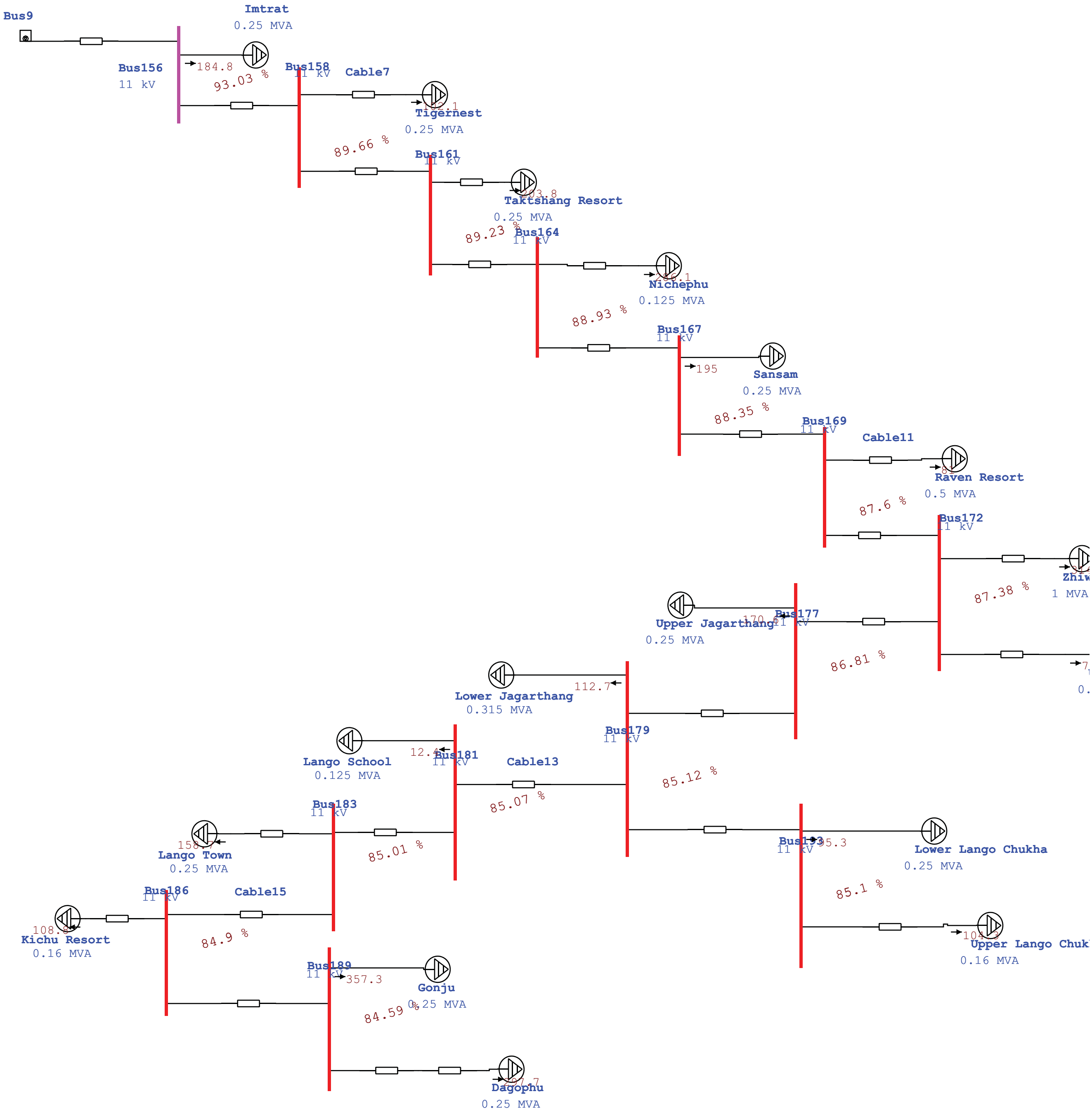
One-Line Diagram - Paro ESD Network=>Ki(H110) (Load Flow Analysis)



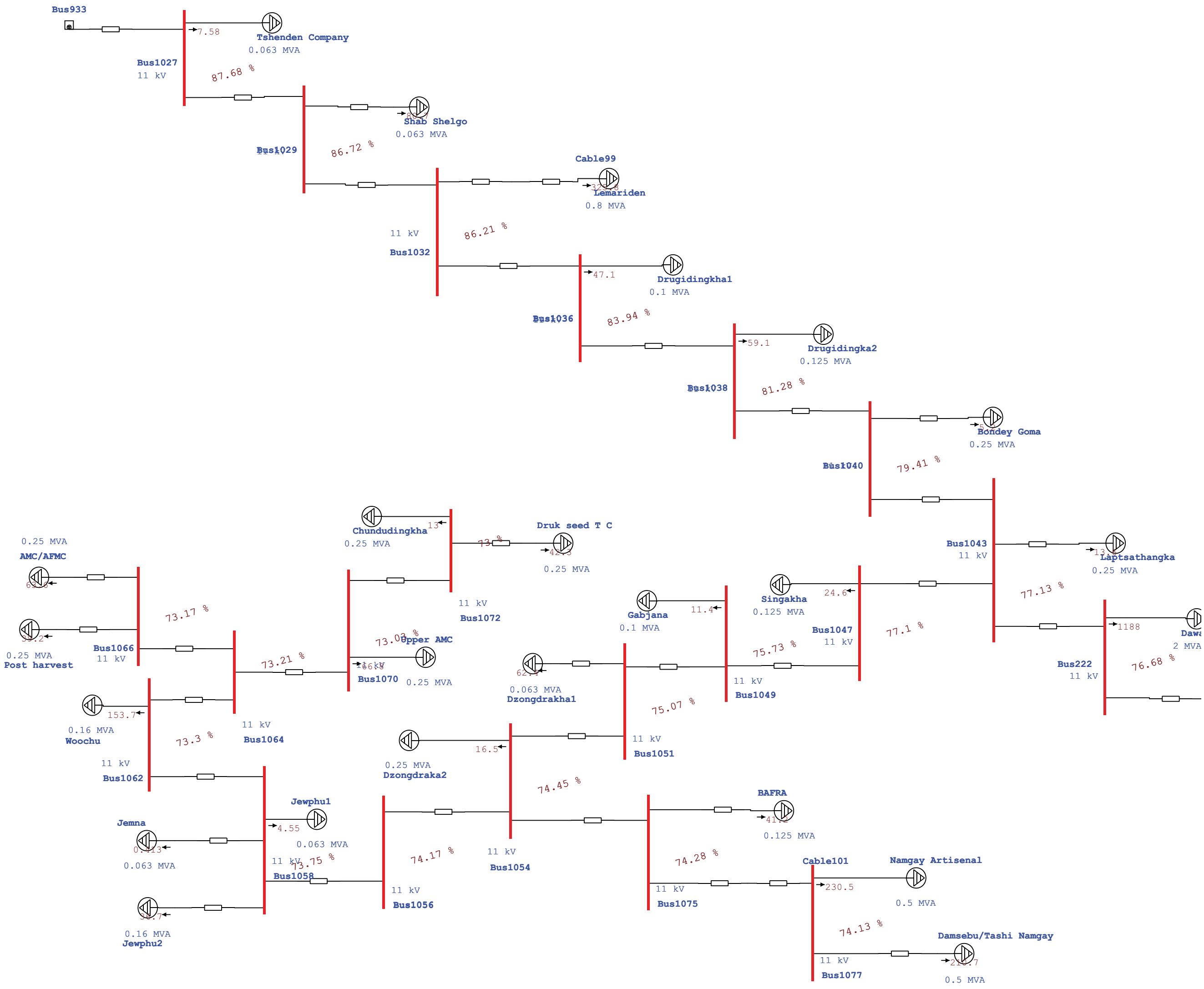
One-Line Diagram - Paro ESD Network=>Ki(H110) (Load Flow Analysis)



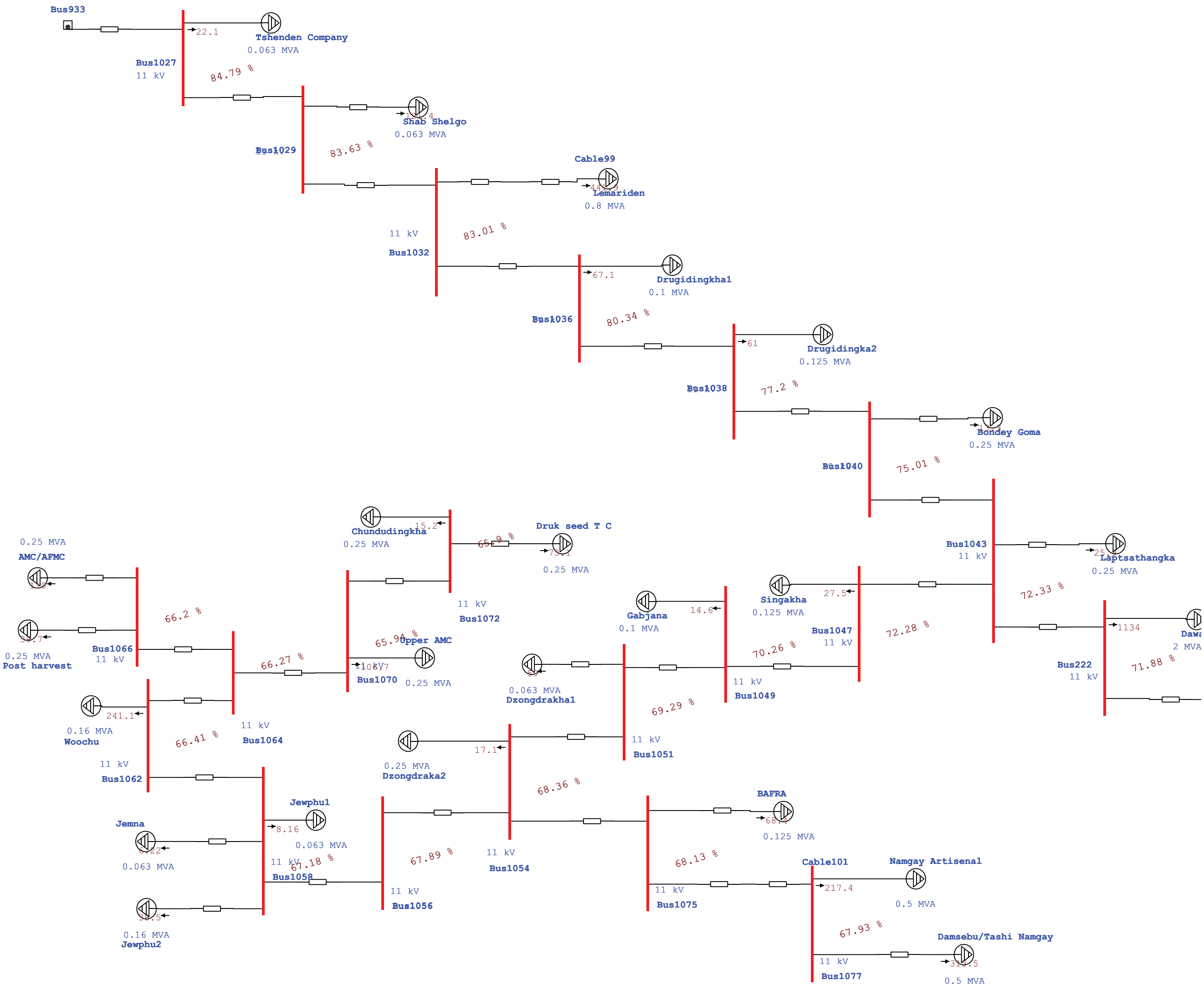
One-Line Diagram - Paro ESD Network=>Ki(H110) (Load Flow Analysis)



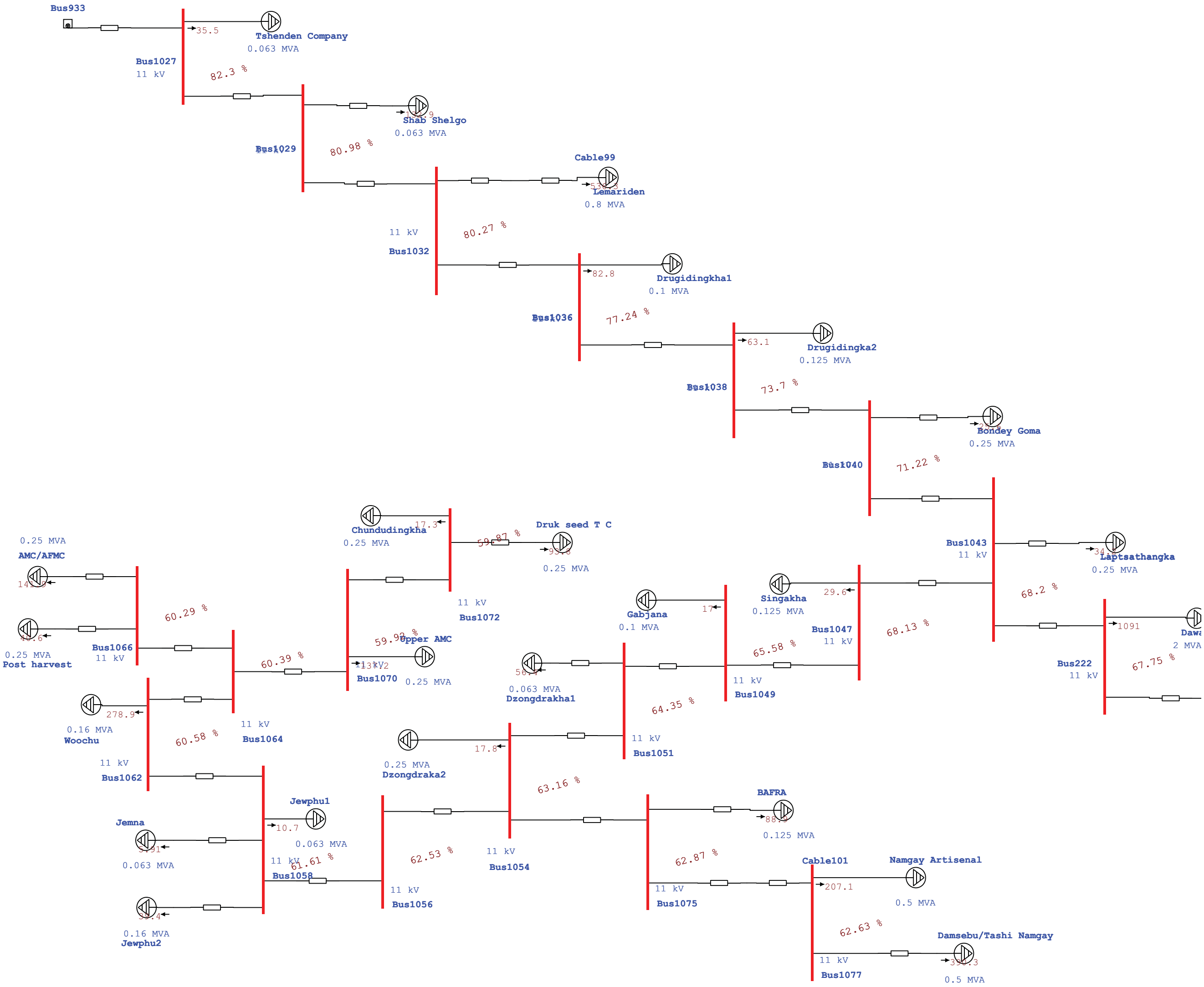
One-Line Diagram - Paro ESD Network=>Drugi(H130) (Load Flow Analysis)



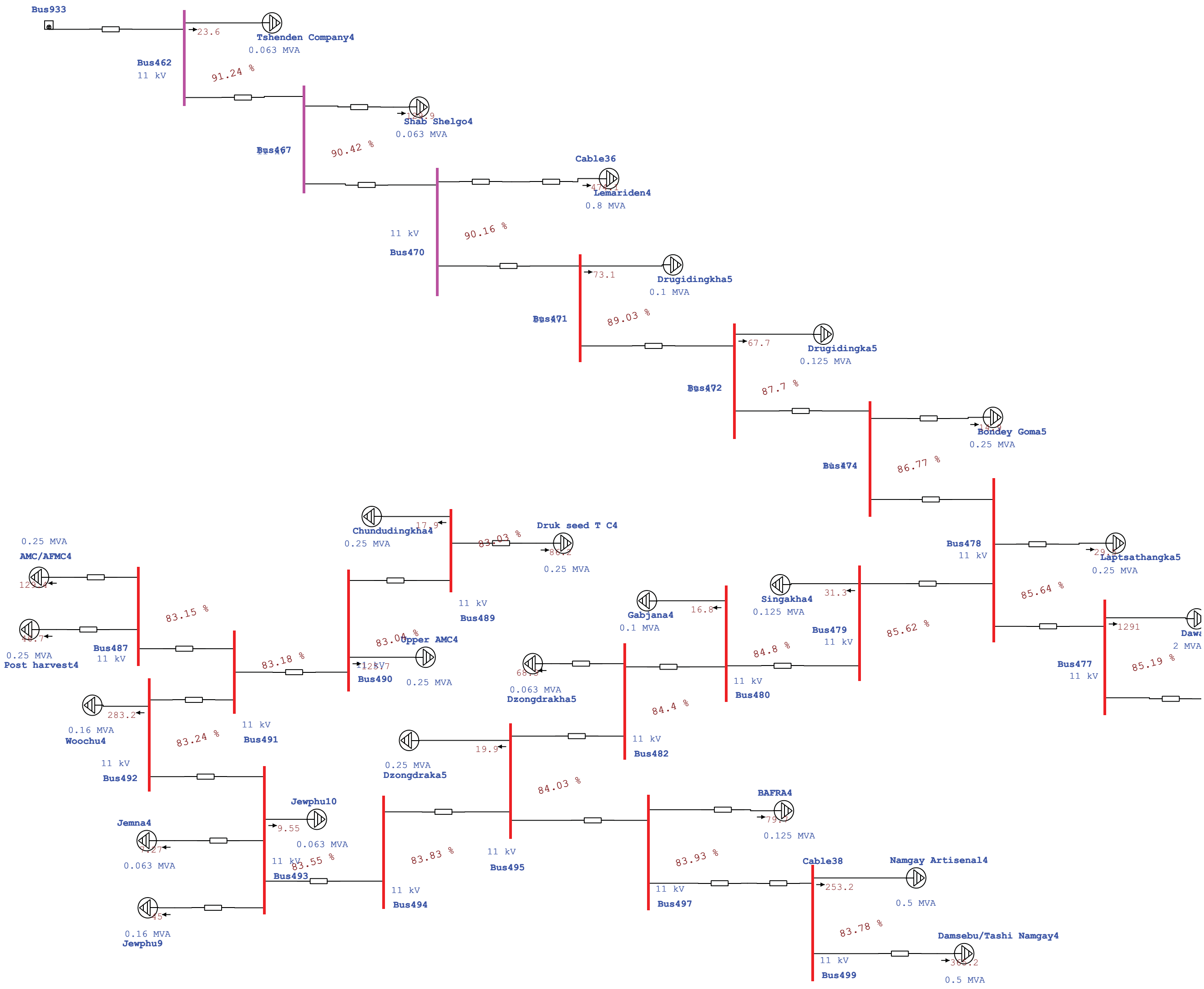
One-Line Diagram - Paro ESD Network=>Drugi(H130) (Load Flow Analysis)



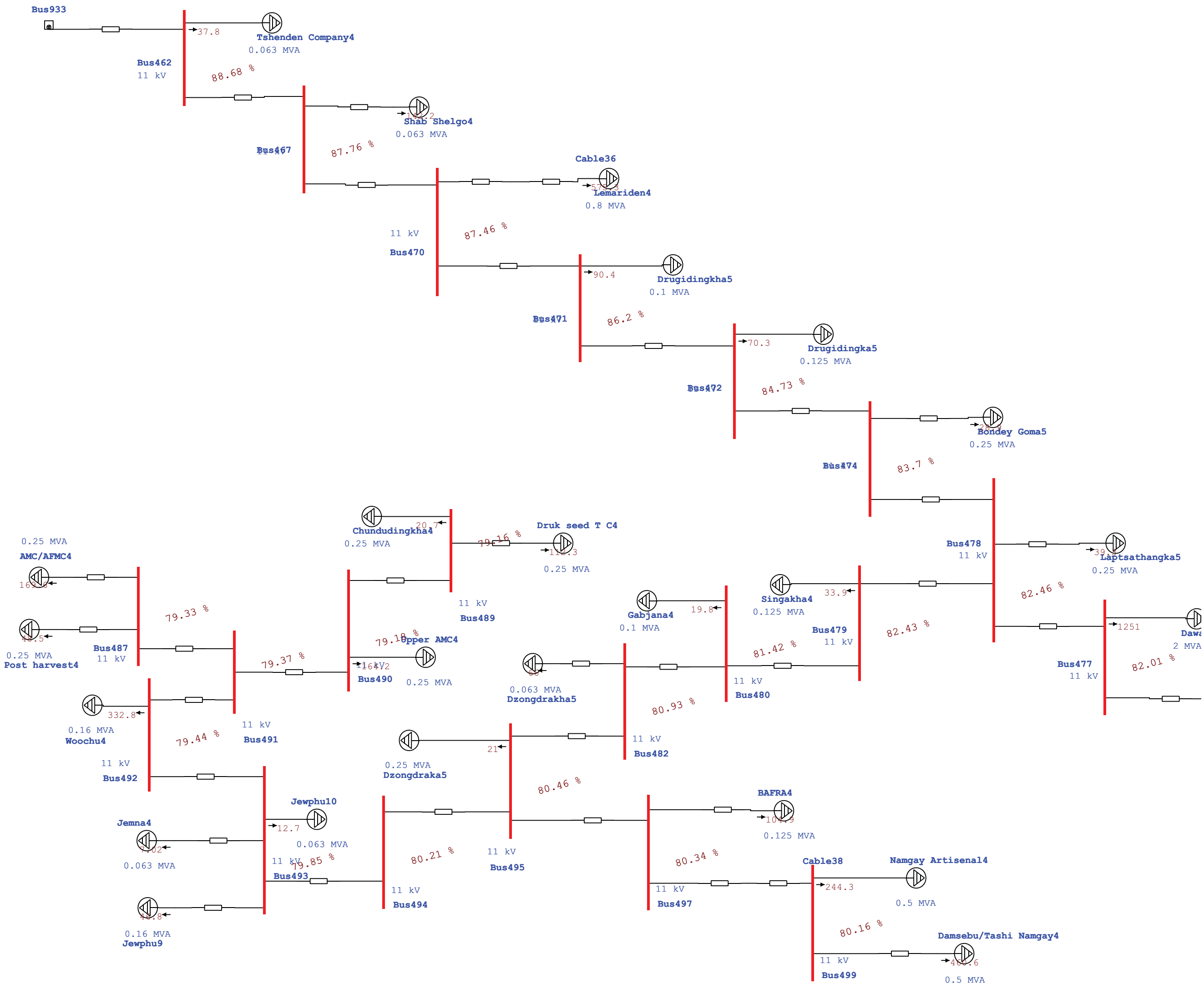
One-Line Diagram - Paro ESD Network=>Drugi(H130) (Load Flow Analysis)



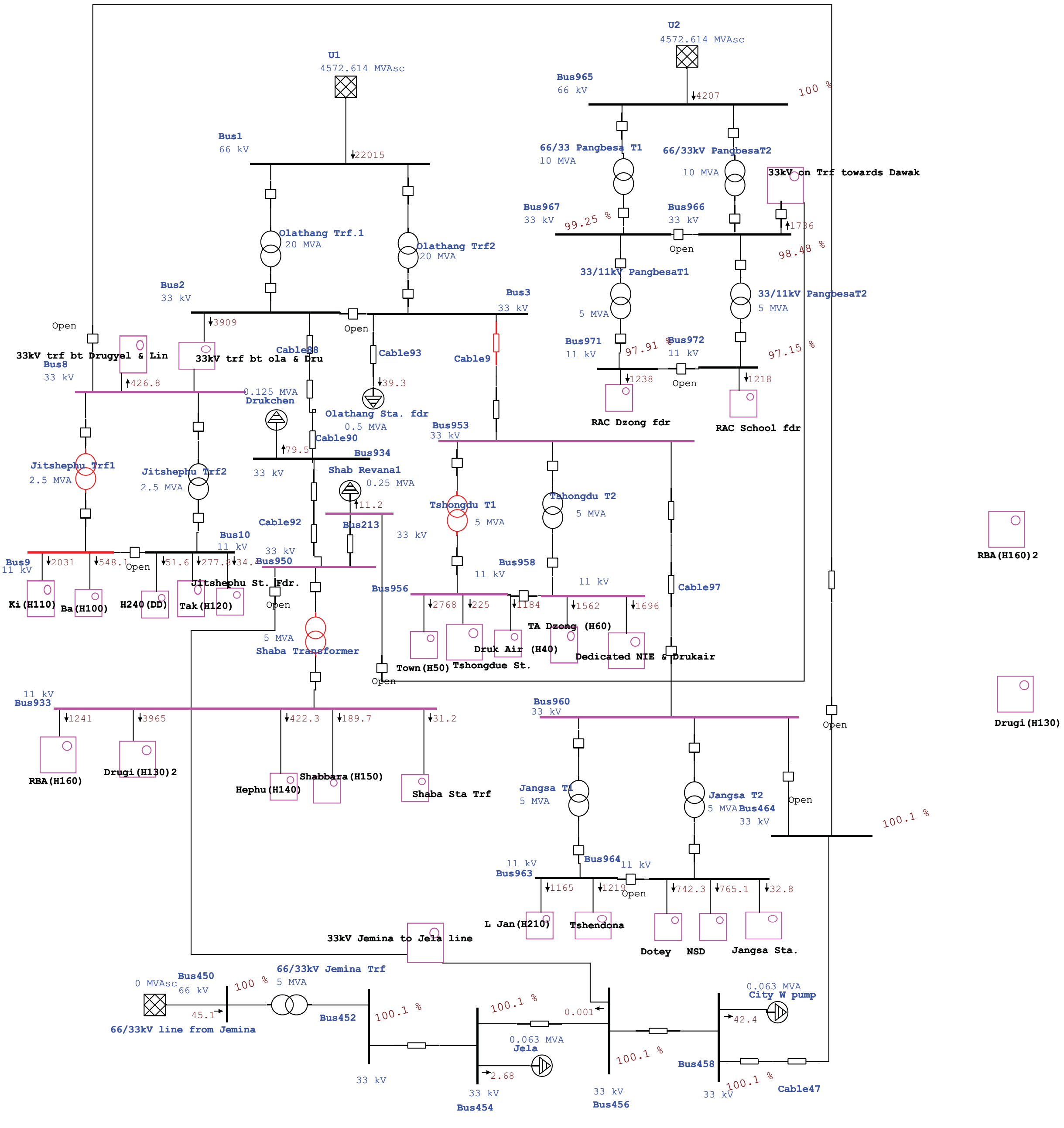
One-Line Diagram - Paro ESD Network=>Drugi(H130)4 (Load Flow Analysis)



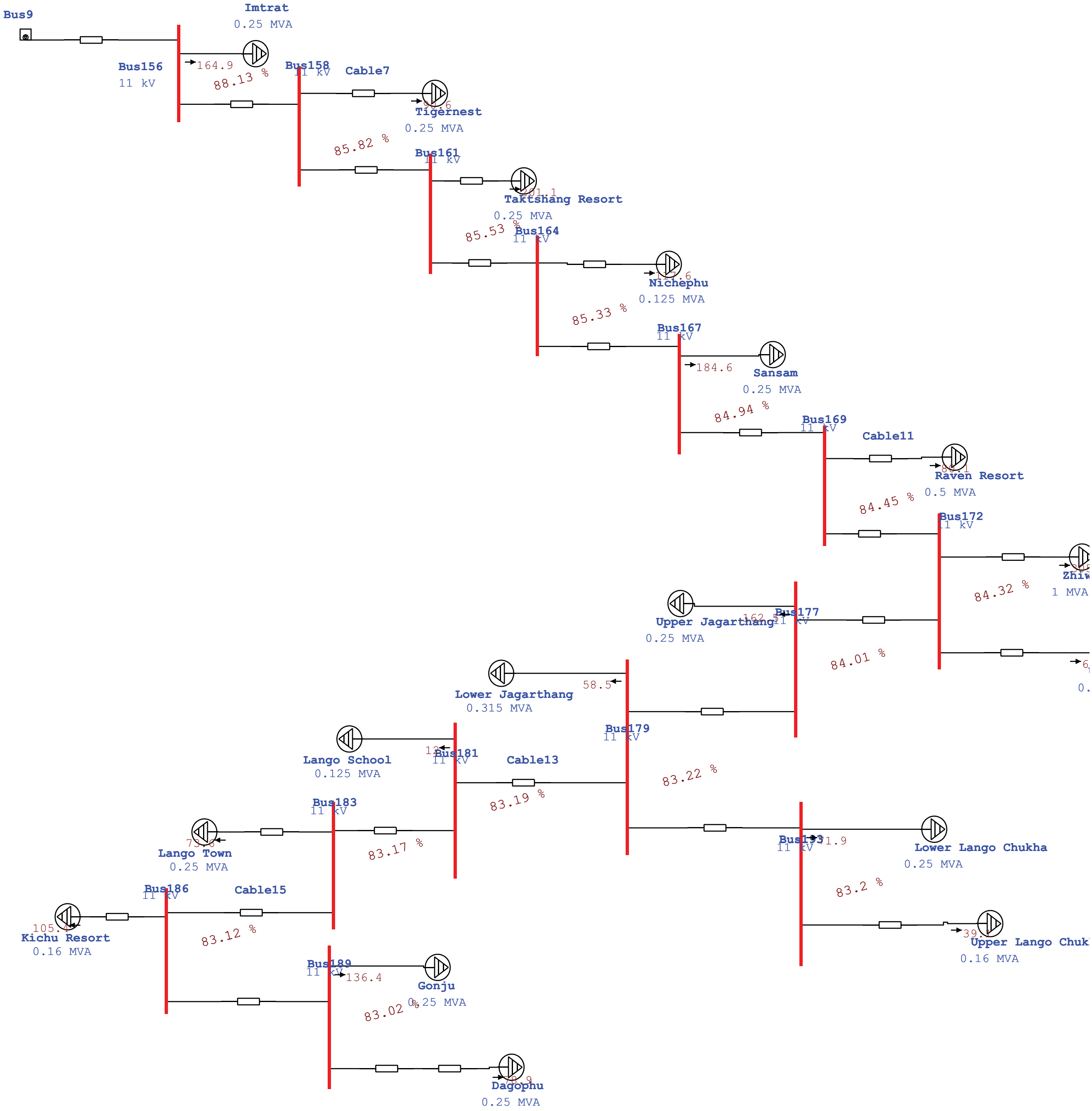
One-Line Diagram - Paro ESD Network=>Drugi(H130)4 (Load Flow Analysis)



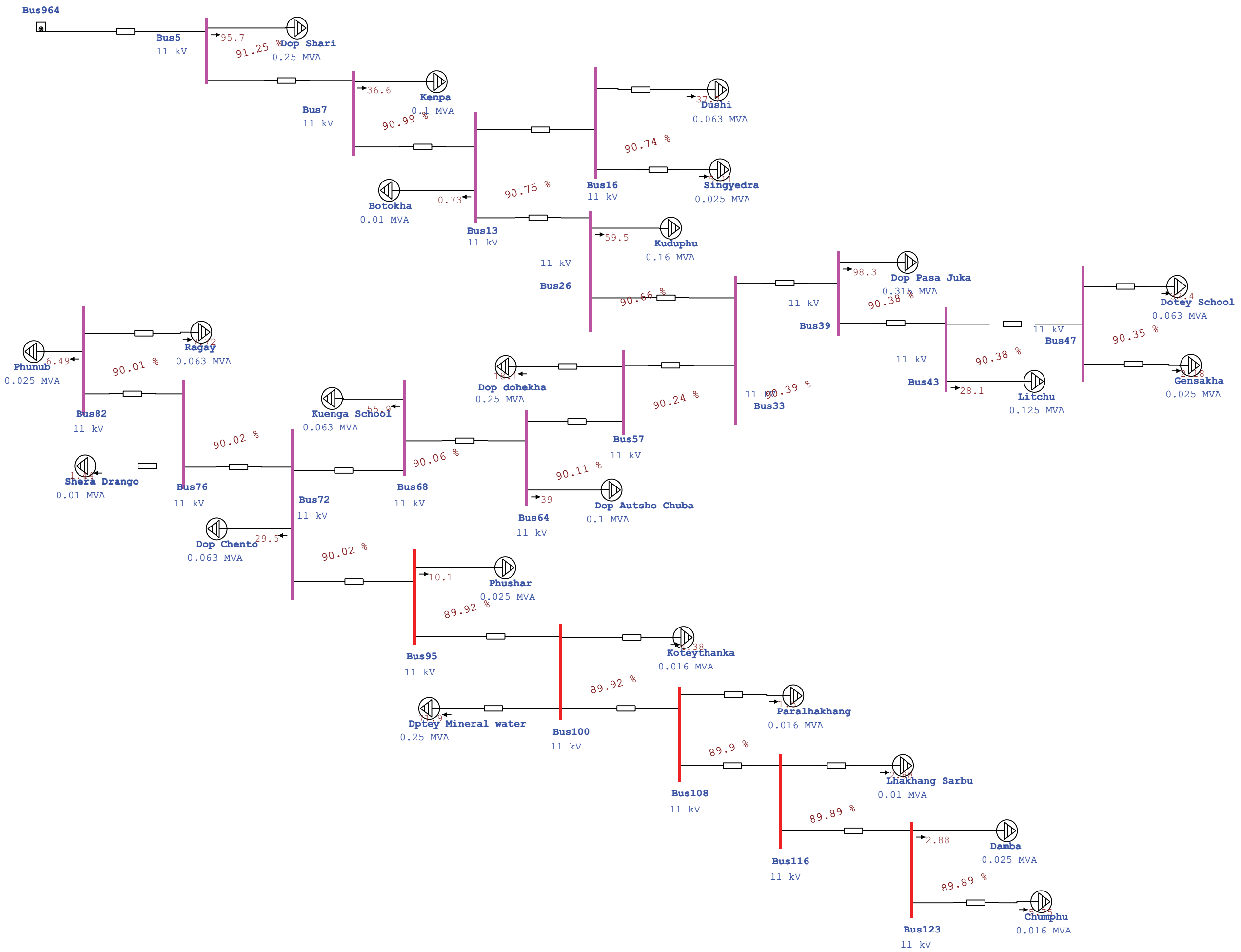
One-Line Diagram - Paro ESD Network (Load Flow Analysis)



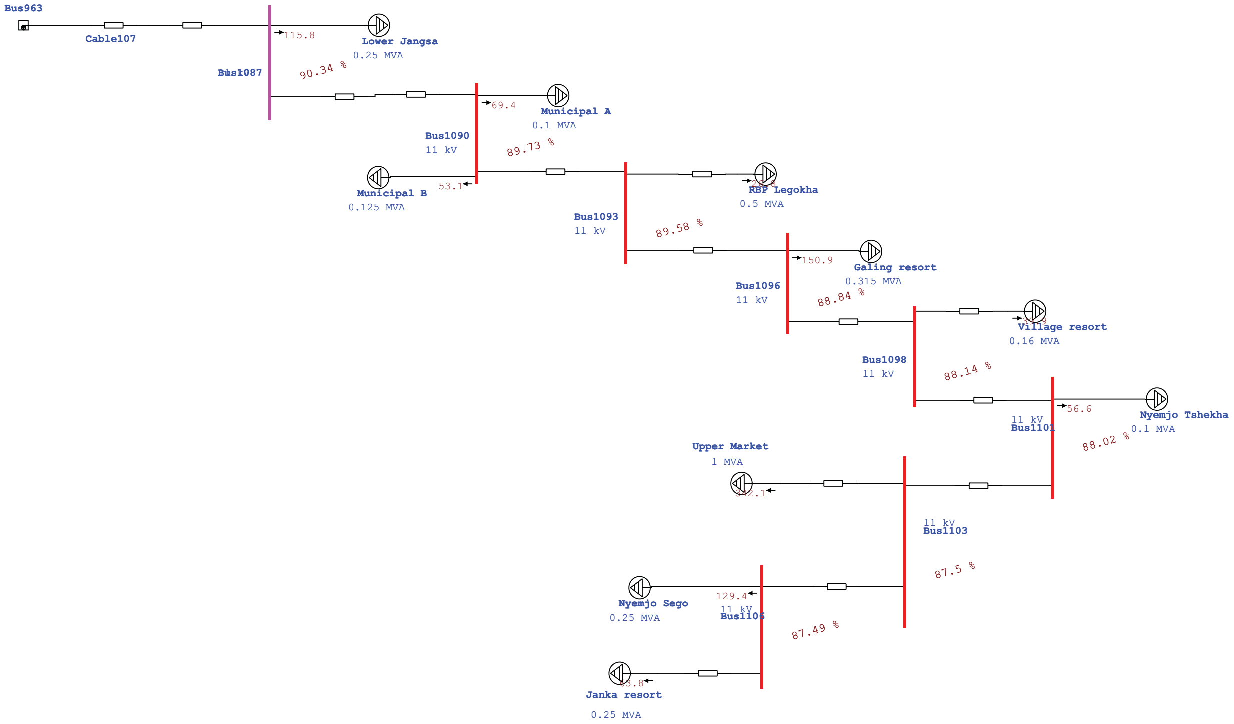
One-Line Diagram - Paro ESD Network=>Ki(H110) (Load Flow Analysis)



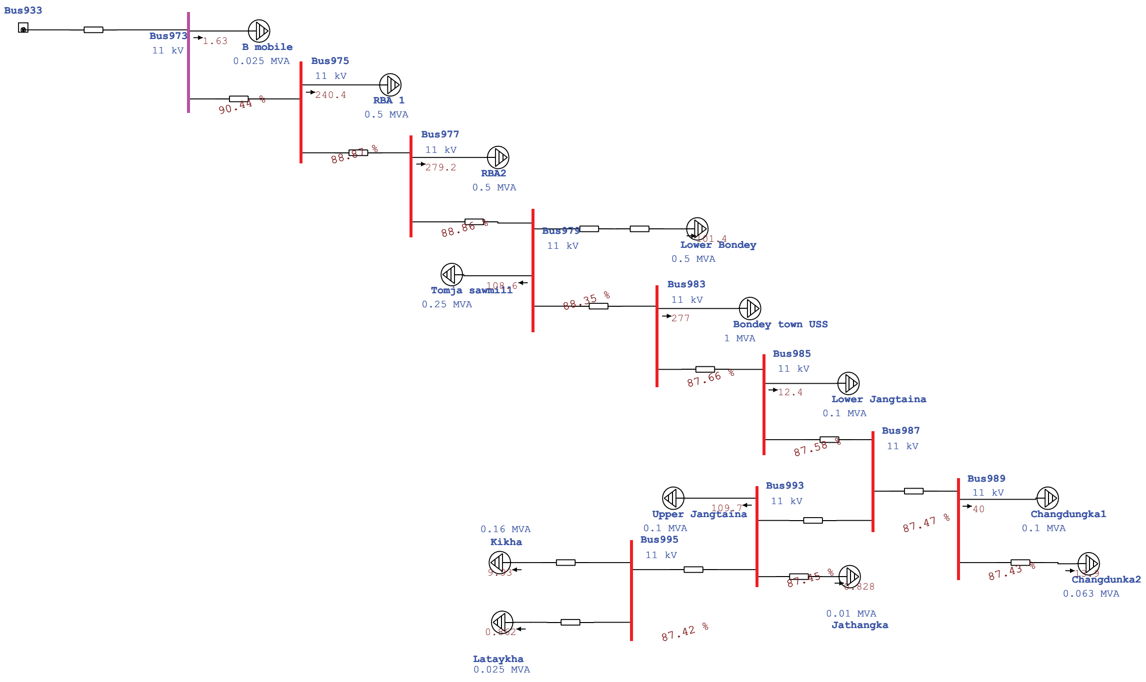
One-Line Diagram - Paro ESD Network=>Dotey (Load Flow Analysis)



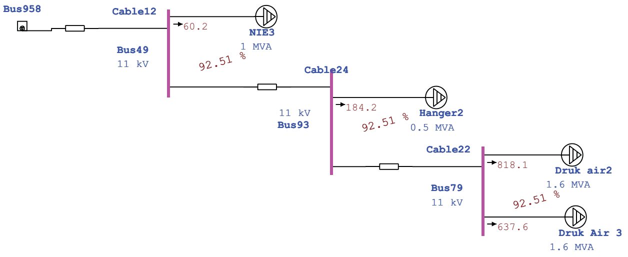
One-Line Diagram - Paro ESD Network=>L Jan(H210) (Load Flow Analysis)



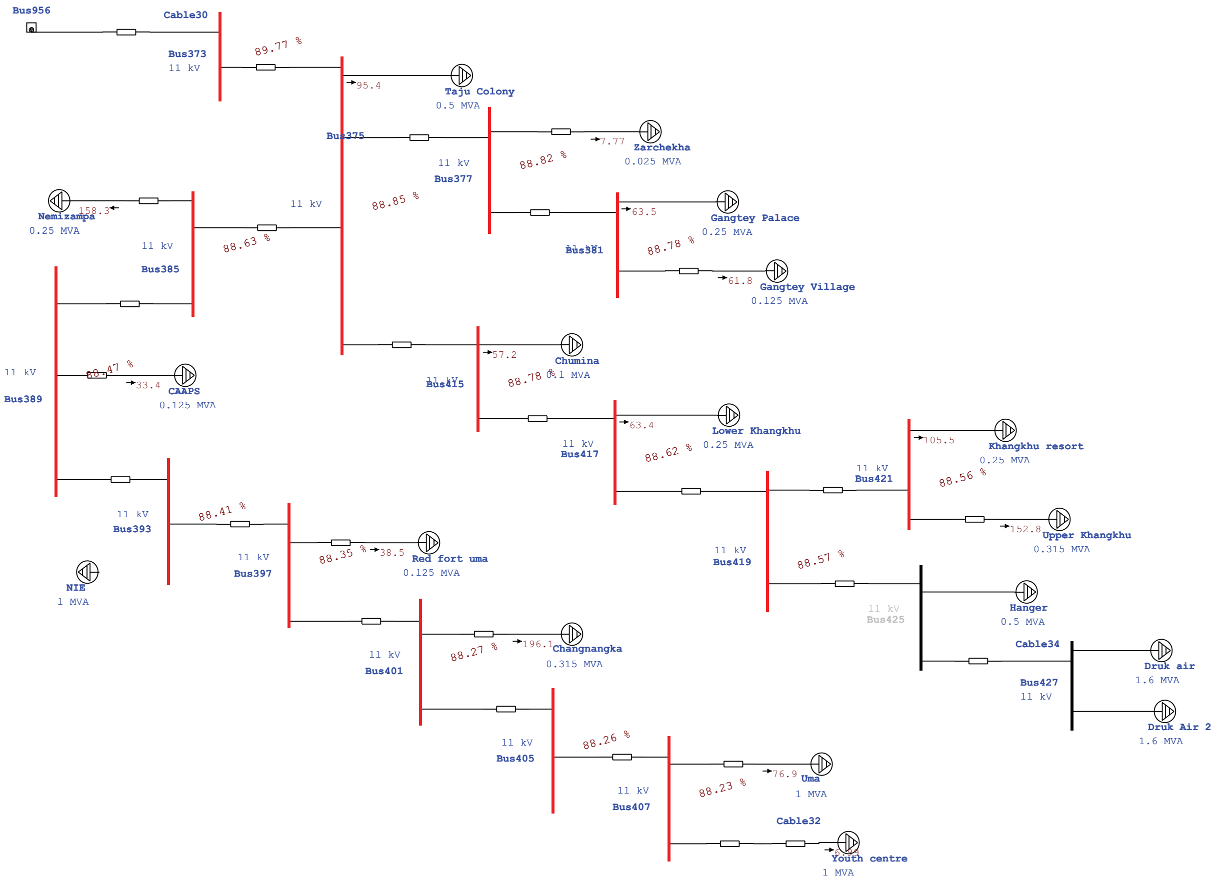
One-Line Diagram - Paro ESD Network=>RBA(H160) (Load Flow Analysis)



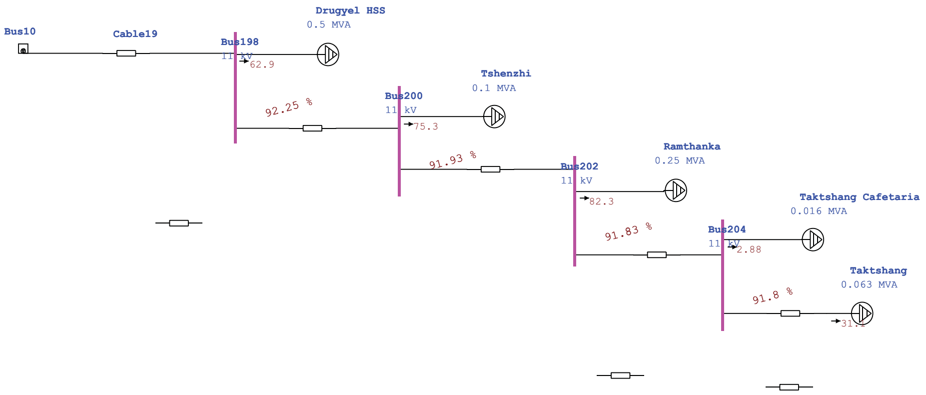
One-Line Diagram - Paro ESD Network=>Dedicated NIE & Drukair (Load Flow Analysis)



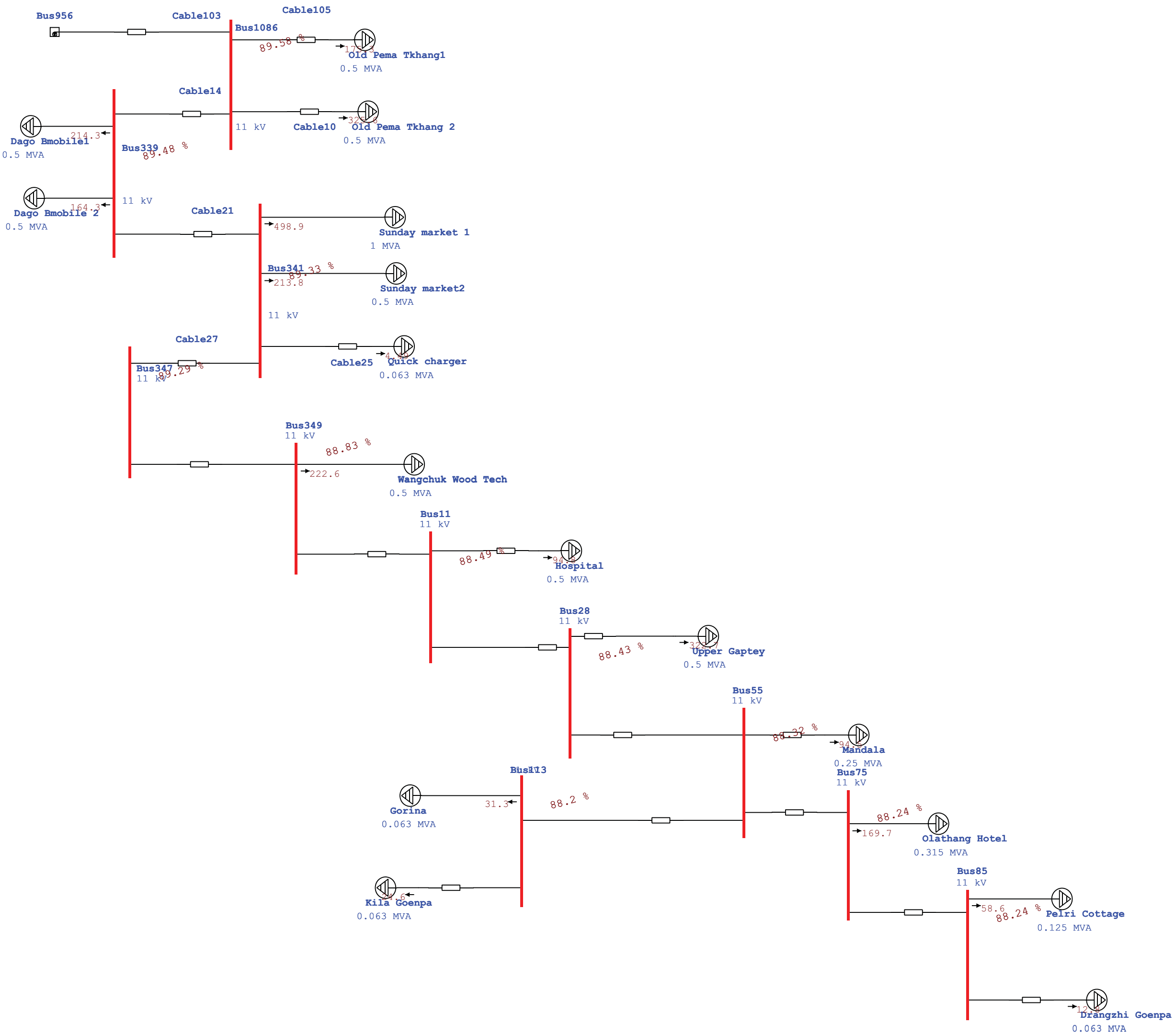
One-Line Diagram - Paro ESD Network=>Druk Air (H40) (Load Flow Analysis)



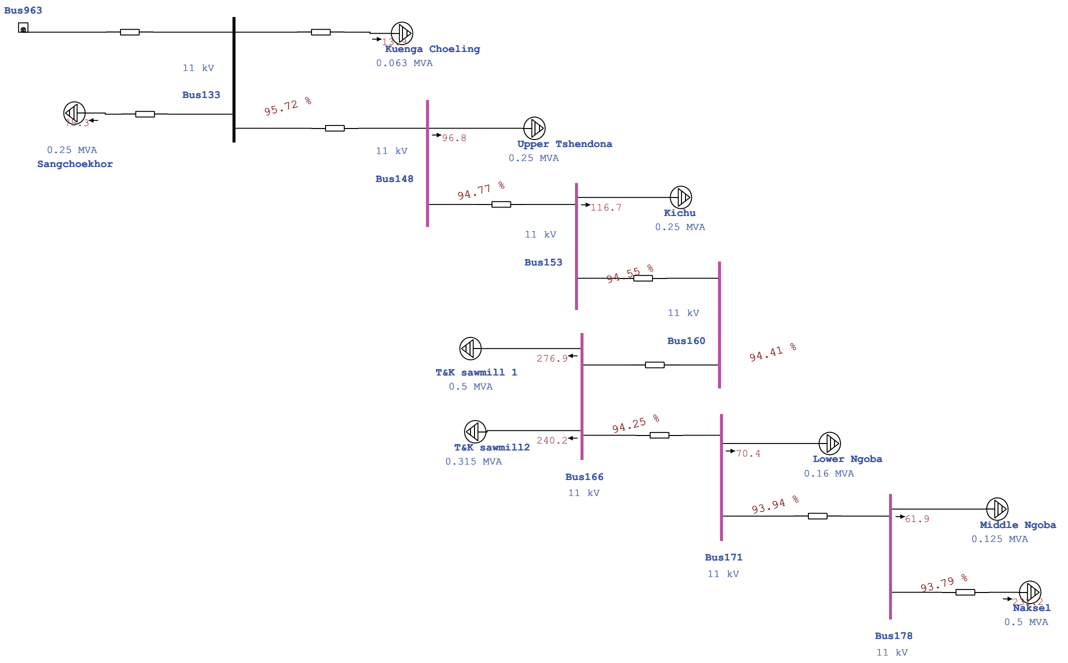
One-Line Diagram - Paro ESD Network=>Tak(H120) (Load Flow Analysis)



One-Line Diagram - Paro ESD Network=>Town(H50) (Load Flow Analysis)



One-Line Diagram - Paro ESD Network=>Tshendona (Load Flow Analysis)



Bus Loading Summary Report

Bus			Directly Connected Load								Total Bus Load			
			Constant kVA		Constant Z		Constant I		Generic					Percent
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Loading
Bus1	66.000										23.499	80.5	205.6	
Bus2	33.000										9.279	84.7	167.0	
Bus3	33.000										13.347	82.4	244.2	
Bus5	11.000		0.022	0.014	0.075	0.046					0.780	85.4	44.6	
Bus6	33.000		0.003	0.002	0.009	0.006					0.014	85.0	0.3	
Bus7	11.000		0.009	0.005	0.029	0.018					0.664	85.5	38.1	
Bus8	33.000										4.052	86.1	74.2	
Bus9	11.000										3.169	84.9	180.3	
Bus10	11.000										1.778	85.0	101.2	
Bus11	11.000										0.952	85.1	56.5	
Bus12	33.000										4.595	86.8	82.7	
Bus13	11.000		0.000	0.000	0.001	-					0.619	85.5	35.6	
Bus14	33.000										4.580	86.8	82.8	
Bus15	11.000		0.023	0.014	0.072	0.045					0.112	85.0	6.6	
Bus16	11.000										0.051	85.2	2.9	
Bus17	11.000		0.009	0.005	0.029	0.018					0.045	85.0	2.6	
Bus18	33.000		0.017	0.010	0.062	0.038					4.536	86.7	82.0	
Bus19	33.000		0.033	0.020	0.008	0.005					0.047	85.0	0.9	
Bus21	11.000		0.001	0.001	0.004	0.002					0.006	85.0	0.3	
Bus22	33.000		0.012	0.007	0.044	0.027					4.438	86.8	80.4	
Bus24	33.000										4.362	86.8	79.3	
Bus25	33.000		0.022	0.014	0.081	0.050					0.122	85.0	2.2	
Bus26	11.000		0.014	0.009	0.046	0.029					0.567	85.5	32.6	
Bus27	33.000		0.010	0.006	0.038	0.023					4.240	86.8	77.1	
Bus28	11.000										0.840	85.1	49.8	
Bus29	33.000										4.177	86.9	76.1	
Bus30	33.000		0.001	0.000	0.002	0.001					0.003	85.0	0.1	
Bus31	33.000										4.165	86.8	76.1	
Bus32	33.000										4.165	86.8	76.1	
Bus33	11.000										0.495	85.6	28.6	
Bus34	33.000										4.165	86.8	76.1	
Bus35	33.000		0.011	0.007	0.041	0.025					0.061	85.0	1.1	
Bus36	33.000										0.444	98.3	8.1	
Bus39	11.000		0.023	0.014	0.076	0.047					0.191	85.2	11.0	
Bus40	11.000		0.078	0.048	0.244	0.151					0.379	85.0	22.5	
Bus41	33.000		0.009	0.005	0.031	0.019					0.052	88.3	1.0	
Bus42	33.000		0.001	0.001	0.005	0.003					0.008	85.0	0.1	
Bus43	11.000		0.007	0.004	0.022	0.014					0.074	85.6	4.3	
Bus44	33.000		0.002	0.001	0.006	0.004					0.398	98.1	7.3	

Bus			Directly Connected Load								Total Bus Load			
			Constant kVA		Constant Z		Constant I		Generic					Percent
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Loading
Bus46	33.000		0.006	0.004	0.022	0.014					0.393	97.3	7.2	
Bus47	11.000										0.041	85.8	2.4	
Bus48	33.000		0.001	0.001	0.003	0.002					0.009	88.5	0.2	
Bus50	11.000		0.008	0.005	0.025	0.016					0.039	85.0	2.2	
Bus51	33.000		0.008	0.005	0.028	0.017					0.361	96.0	6.6	
Bus52	11.000		0.001	0.000	0.002	0.001					0.003	85.0	0.1	
Bus53	33.000										0.333	93.4	6.1	
Bus54	33.000		0.008	0.005	0.028	0.017					0.041	85.0	0.8	
Bus55	11.000										0.459	85.2	27.3	
Bus56	33.000		0.003	0.002	0.011	0.007					0.299	92.1	5.5	
Bus57	11.000										0.304	85.8	17.6	
Bus58	33.000		0.002	0.001	0.006	0.004					0.285	91.5	5.2	
Bus59	11.000		0.004	0.003	0.014	0.009					0.022	85.0	1.2	
Bus60	33.000										0.276	91.8	5.1	
Bus63	33.000		0.011	0.007	0.041	0.025					0.290	87.4	5.3	
Bus64	11.000		0.009	0.006	0.030	0.019					0.282	85.8	16.3	
Bus65	33.000		0.003	0.002	0.009	0.006					0.245	81.9	4.5	
Bus66	11.000		0.023	0.014	0.072	0.044					0.111	85.0	6.6	
Bus67	33.000		0.000	0.000	0.001	-					0.227	83.3	4.2	
Bus68	11.000		0.013	0.008	0.043	0.027					0.236	85.9	13.7	
Bus69	33.000										0.224	84.1	4.1	
Bus71	33.000		0.000	0.000	0.001	0.001					0.032	66.1	0.6	
Bus72	11.000		0.007	0.004	0.023	0.014					0.169	86.3	9.8	
Bus73	33.000										0.026	74.4	0.5	
Bus74	33.000		0.001	0.001	0.004	0.002					0.006	85.0	0.1	
Bus75	11.000		0.041	0.026	0.128	0.080					0.283	85.0	16.9	
Bus76	11.000										0.018	87.7	1.0	
Bus77	11.000		0.000	0.000	0.001	0.001					0.002	85.0	0.1	
Bus78	33.000		0.000	0.000	0.001	0.001					0.018	84.2	0.3	
Bus80	33.000		0.002	0.001	0.006	0.003					0.015	86.5	0.3	
Bus81	33.000		0.001	0.001	0.005	0.003					0.007	85.0	0.1	
Bus82	11.000		0.002	0.001	0.005	0.003					0.017	86.7	1.0	
Bus83	33.000										0.020	71.7	0.4	
Bus84	33.000		0.002	0.001	0.006	0.003					0.008	85.0	0.2	
Bus85	11.000		0.014	0.009	0.044	0.027					0.084	85.1	5.0	
Bus86	33.000										0.007	94.4	0.1	
Bus87	33.000		0.001	0.001	0.003	0.002					0.005	85.0	0.1	
Bus89	33.000		0.001	0.000	0.002	0.002					0.004	85.0	0.1	
Bus91	11.000		0.002	0.001	0.006	0.004					0.009	85.0	0.5	
Bus92	33.000		0.000	0.000	0.001	-					0.161	94.6	3.0	
Bus94	33.000		0.000	0.000	0.001	0.001					0.159	95.6	2.9	
Bus95	11.000		0.002	0.001	0.008	0.005					0.116	86.3	6.8	

Bus			**Directly Connected Load**								**Total Bus Load**			
			Constant kVA		Constant Z		Constant I		Generic					Percent
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Loading
Bus96	33.000										0.156	96.3	2.9	
Bus97	11.000		0.003	0.002	0.010	0.006					0.015	85.0	0.9	
Bus98	33.000		0.001	0.000	0.002	0.001					0.009	43.9	0.2	
Bus99	33.000		0.000	0.000	0.001	0.001					0.002	85.0	-	
Bus100	11.000										0.104	86.4	6.1	
Bus101	33.000		0.001	0.001	0.004	0.002					0.147	99.2	2.7	
Bus102	11.000		0.017	0.011	0.056	0.034					0.085	85.0	5.0	
Bus103	33.000		0.001	0.000	0.002	0.001					0.142	99.3	2.6	
Bus104	11.000		0.001	0.001	0.003	0.002					0.005	85.0	0.3	
Bus105	33.000		0.001	0.000	0.002	0.002					0.140	99.5	2.6	
Bus107	33.000		0.004	0.002	0.014	0.008					0.137	98.8	2.5	
Bus108	11.000										0.014	91.5	0.8	
Bus109	33.000		0.001	0.001	0.004	0.003					0.120	99.0	2.2	
Bus110	11.000		0.000	0.000	0.001	0.001					0.002	85.0	0.1	
Bus111	33.000										0.114	98.8	2.1	
Bus112	33.000		0.000	0.000	0.001	0.001					0.002	85.0	-	
Bus113	11.000		0.008	0.005	0.024	0.015					0.065	86.0	3.9	
Bus114	33.000										0.113	98.1	2.1	
Bus115	33.000		0.001	0.000	0.002	0.001					0.003	85.0	0.1	
Bus116	11.000										0.013	90.0	0.7	
Bus117	33.000										0.113	96.5	2.1	
Bus118	33.000		0.003	0.002	0.010	0.006					0.015	85.0	0.3	
Bus119	11.000		0.001	0.000	0.002	0.001					0.003	85.0	0.2	
Bus120	33.000		0.002	0.001	0.006	0.003					0.099	97.2	1.8	
Bus122	33.000		0.000	0.000	0.001	-					0.091	97.7	1.7	
Bus123	11.000		0.001	0.000	0.002	0.001					0.010	90.7	0.6	
Bus124	33.000										0.091	97.6	1.7	
Bus125	11.000		0.001	0.001	0.004	0.003					0.007	85.0	0.4	
Bus126	33.000										0.064	96.3	1.2	
Bus127	11.000		0.078	0.048	0.266	0.165					0.810	85.0	46.1	
Bus128	33.000										0.032	87.8	0.6	
Bus130	11.000		0.078	0.048	0.266	0.165					0.405	85.0	23.1	
Bus131	11.000		0.017	0.010	0.014	0.009					0.036	85.0	2.1	
Bus132	33.000		0.001	0.000	0.002	0.001					0.003	85.0	0.1	
Bus133	11.000										1.327	85.1	78.0	
Bus134	33.000		0.003	0.002	0.010	0.006					0.030	86.0	0.6	
Bus135	33.000		0.003	0.002	0.010	0.006					0.016	85.0	0.3	
Bus137	33.000		0.004	0.003	0.015	0.009					0.035	94.2	0.6	
Bus138	11.000		0.007	0.004	0.006	0.004					0.015	85.0	0.9	
Bus139	33.000		0.003	0.002	0.010	0.006					0.016	86.3	0.3	
Bus140	33.000		0.000	0.000	0.001	-					0.001	85.0	-	
Bus141	11.000		0.039	0.024	0.031	0.019					0.083	85.0	4.9	

Bus			Directly Connected Load								Total Bus Load			
			Constant kVA		Constant Z		Constant I		Generic					
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Percent Loading
Bus142	33.000										0.031	89.1	0.6	
Bus143	33.000		0.001	0.001	0.003	0.002					0.004	85.0	0.1	
Bus144	11.000		0.006	0.004	0.019	0.012					0.029	85.0	1.7	
Bus145	33.000		0.003	0.002	0.010	0.006					0.028	85.6	0.5	
Bus146	33.000		0.002	0.001	0.009	0.005					0.013	85.0	0.2	
Bus147	11.000		0.068	0.042	0.135	0.084					0.682	85.0	38.9	
Bus148	11.000		0.051	0.032	0.040	0.025					1.216	85.1	72.2	
Bus149	11.000										0.443	85.1	25.3	
Bus150	11.000		0.007	0.004	0.014	0.009					0.025	85.0	1.4	
Bus151	11.000										1.732	85.1	102.5	
Bus152	11.000		0.013	0.008	0.025	0.015					0.418	85.1	23.9	
Bus153	11.000		0.062	0.038	0.048	0.030					1.106	85.1	65.9	
Bus154	11.000		0.028	0.017	0.055	0.034					0.373	85.0	21.4	
Bus155	11.000		0.079	0.049	0.155	0.096					0.275	85.0	15.8	
Bus156	11.000		0.059	0.036	0.116	0.072					2.485	84.9	141.4	
Bus157	11.000										0.413	85.0	24.5	
Bus158	11.000										2.223	85.1	129.7	
Bus159	11.000		0.077	0.047	0.015	0.010					0.108	85.0	6.3	
Bus160	11.000										0.976	85.1	58.2	
Bus161	11.000										2.108	85.1	123.4	
Bus162	11.000		0.170	0.105	0.034	0.021					0.240	85.0	14.1	
Bus163	11.000		0.085	0.053	0.266	0.165					0.413	85.0	24.5	
Bus164	11.000										1.863	85.1	109.4	
Bus165	11.000		0.099	0.062	0.020	0.012					0.140	85.0	8.2	
Bus166	11.000		0.274	0.170	0.211	0.131					0.974	85.0	58.2	
Bus167	11.000		0.156	0.097	0.031	0.019					1.716	85.1	101.1	
Bus169	11.000										1.487	85.1	88.1	
Bus170	11.000		0.068	0.042	0.013	0.008					0.096	85.0	5.7	
Bus171	11.000		0.037	0.023	0.029	0.018					0.402	85.1	24.1	
Bus172	11.000										1.389	85.1	82.5	
Bus173	11.000		0.179	0.111	0.139	0.086					0.374	85.0	22.2	
Bus175	11.000		0.040	0.025	0.032	0.020					0.085	85.0	5.0	
Bus176	11.000		0.028	0.017	0.088	0.055					1.318	85.1	78.0	
Bus177	11.000		0.043	0.026	0.132	0.082					0.927	85.1	55.2	
Bus178	11.000		0.033	0.020	0.025	0.016					0.324	85.0	19.5	
Bus179	11.000		0.016	0.010	0.047	0.029					0.716	85.1	43.0	
Bus180	11.000		0.123	0.076	0.094	0.058					0.255	85.0	15.4	
Bus181	11.000		0.003	0.002	0.010	0.006					0.506	85.1	30.4	
Bus183	11.000										0.490	85.1	29.5	
Bus184	11.000		0.020	0.012	0.060	0.037					0.093	85.0	5.6	
Bus186	11.000										0.397	85.1	23.9	
Bus187	11.000		0.028	0.017	0.085	0.053					0.133	85.0	8.0	

Bus			Directly Connected Load								Total Bus Load			
			Constant kVA		Constant Z		Constant I		Generic					
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Percent Loading
Bus188	33.000										1.454	92.7	26.1	
Bus189	11.000		0.081	0.050	0.061	0.038					0.264	85.1	15.9	
Bus190	11.000										0.097	85.2	5.8	
Bus191	11.000		0.047	0.029	0.035	0.022					0.097	85.0	5.8	
Bus193	11.000		0.043	0.026	0.032	0.020					0.136	85.1	8.2	
Bus194	11.000		0.023	0.014	0.018	0.011					0.048	85.0	2.9	
Bus195	11.000										0.054	85.3	3.0	
Bus196	11.000										0.054	85.0	3.1	
Bus197	11.000		0.015	0.009	0.030	0.019					0.054	85.0	3.1	
Bus198	11.000		0.034	0.021	0.029	0.018					0.299	85.3	17.0	
Bus199	33.000		0.018	0.011	0.017	0.011					1.454	92.7	26.1	
Bus200	11.000		0.041	0.025	0.034	0.021					0.225	85.3	12.8	
Bus202	11.000		0.045	0.028	0.038	0.023					0.136	85.3	7.8	
Bus204	11.000		0.002	0.001	0.001	0.001					0.040	85.3	2.3	
Bus205	11.000		0.017	0.010	0.014	0.009					0.037	85.0	2.1	
Bus206	11.000		0.007	0.004	0.023	0.014					0.035	85.0	2.0	
Bus214	33.000		0.064	0.040	0.061	0.038					1.922	91.4	34.4	
Bus219	33.000										1.414	92.7	25.5	
Bus220	33.000										1.414	92.7	25.5	
Bus221	33.000		0.013	0.008	0.012	0.008					0.029	85.0	0.5	
Bus223	33.000										1.385	92.7	25.0	
Bus227	33.000		0.026	0.016	0.024	0.015					0.059	85.0	1.1	
Bus229	33.000										1.351	91.3	24.4	
Bus231	33.000										0.153	88.9	2.8	
Bus233	33.000		0.016	0.010	0.015	0.009					0.037	85.0	0.7	
Bus237	33.000		0.010	0.006	0.009	0.006					0.118	88.8	2.1	
Bus239	33.000										0.096	88.9	1.7	
Bus241	33.000		0.028	0.017	0.026	0.016					0.064	85.0	1.2	
Bus243	33.000		0.008	0.005	0.007	0.005					0.035	88.2	0.6	
Bus245	33.000		0.008	0.005	0.007	0.004					0.018	85.0	0.3	
Bus247	33.000										1.229	89.3	22.2	
Bus249	33.000		0.025	0.015	0.023	0.015					0.057	85.0	1.0	
Bus251	33.000										1.175	89.1	21.2	
Bus253	33.000		0.010	0.006	0.009	0.006					0.023	85.0	0.4	
Bus256	33.000										1.158	88.6	21.0	
Bus258	33.000		0.016	0.010	0.015	0.009					0.037	85.0	0.7	
Bus260	33.000		0.015	0.009	0.014	0.009					1.129	88.1	20.4	
Bus262	33.000		0.005	0.003	0.005	0.003					0.012	85.0	0.2	
Bus264	33.000										1.083	88.2	19.6	
Bus266	33.000										0.071	91.9	1.3	
Bus268	33.000		0.007	0.004	0.006	0.004					0.027	88.0	0.5	
Bus270	33.000		0.006	0.003	0.005	0.003					0.013	85.0	0.2	

Bus			Directly Connected Load								Total Bus Load			
			Constant kVA		Constant Z		Constant I		Generic					
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Percent Loading
Bus272	33.000		0.008	0.005	0.007	0.004					0.046	89.8	0.8	
Bus274	33.000										0.030	89.1	0.5	
Bus276	33.000		0.005	0.003	0.005	0.003					0.012	85.0	0.2	
Bus277	33.000		0.009	0.005	0.008	0.005					0.019	85.0	0.4	
Bus279	33.000		0.043	0.026	0.040	0.025					1.015	87.6	18.4	
Bus281	33.000		0.128	0.079	0.119	0.074					0.290	85.0	5.3	
Bus283	33.000										0.631	89.0	11.4	
Bus286	33.000		0.013	0.008	0.012	0.007					0.029	85.0	0.5	
Bus288	33.000		0.053	0.033	0.049	0.031					0.607	88.4	11.0	
Bus290	33.000		0.017	0.010	0.016	0.010					0.487	89.0	8.8	
Bus292	33.000										0.450	89.1	8.2	
Bus294	33.000													
Bus296	33.000		0.010	0.006	0.009	0.006					0.451	88.9	8.2	
Bus298	33.000										0.430	88.7	7.8	
Bus305	33.000		0.013	0.008	0.012	0.007					0.420	88.3	7.6	
Bus307	33.000		0.043	0.026	0.039	0.024					0.170	85.1	3.1	
Bus308	33.000		0.033	0.020	0.030	0.019					0.074	85.0	1.3	
Bus310	33.000		0.016	0.010	0.015	0.009					0.226	89.3	4.1	
Bus312	33.000		0.003	0.002	0.002	0.002					0.006	85.0	0.1	
Bus314	33.000		0.009	0.005	0.008	0.005					0.186	88.9	3.4	
Bus316	33.000										0.166	89.2	3.0	
Bus318	33.000		0.009	0.005	0.008	0.005					0.019	85.0	0.4	
Bus320	33.000		0.020	0.012	0.018	0.011					0.150	87.8	2.7	
Bus322	33.000										0.107	88.5	1.9	
Bus324	33.000		0.006	0.003	0.005	0.003					0.013	85.0	0.2	
Bus326	33.000										0.095	87.6	1.7	
Bus328	33.000		0.025	0.015	0.023	0.014					0.056	85.0	1.0	
Bus330	33.000		0.006	0.004	0.005	0.003					0.041	87.3	0.8	
Bus332	33.000										0.029	86.9	0.5	
Bus334	33.000		0.013	0.008	0.012	0.007					0.029	85.0	0.5	
Bus335	11.000		0.042	0.026	0.133	0.082					0.205	85.0	12.1	
Bus337	11.000		0.077	0.048	0.247	0.153					0.381	85.0	22.4	
Bus339	11.000		0.090	0.056	0.287	0.178					2.510	85.0	147.6	
Bus341	11.000		0.170	0.105	0.542	0.336					2.066	85.1	121.5	
Bus345	11.000		0.001	0.001	0.003	0.002					0.005	85.0	0.3	
Bus347	11.000										1.223	85.1	71.9	
Bus349	11.000		0.054	0.033	0.169	0.105					1.217	85.1	71.9	
Bus351	11.000		0.006	0.004	0.019	0.012					1.178	85.1	70.0	
Bus353	11.000		0.006	0.004	0.019	0.012					1.146	85.1	68.2	
Bus355	11.000		0.013	0.008	0.039	0.024					0.689	85.0	41.3	
Bus357	11.000		0.128	0.079	0.391	0.242					0.610	85.0	36.6	
Bus358	11.000		0.004	0.002	0.012	0.007					0.018	85.0	1.1	

Bus			Directly Connected Load								Total Bus Load			
			Constant kVA		Constant Z		Constant I		Generic					
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Percent Loading
Bus361	11.000										0.380	85.1	22.7	
Bus362	11.000		0.009	0.005	0.026	0.016					0.421	85.1	25.2	
Bus364	11.000		0.036	0.022	0.111	0.069					0.189	85.2	11.3	
Bus366	11.000		0.002	0.001	0.006	0.004					0.016	85.8	0.9	
Bus368	11.000		0.001	0.001	0.004	0.003					0.007	85.0	0.4	
Bus370	11.000		0.014	0.008	0.042	0.026					0.192	85.0	11.5	
Bus372	11.000		0.026	0.016	0.081	0.050					0.126	85.0	7.6	
Bus373	11.000										3.238	85.1	187.2	
Bus375	11.000		0.023	0.014	0.072	0.045					3.159	84.9	187.2	
Bus377	11.000										0.156	85.1	9.2	
Bus379	11.000		0.002	0.001	0.006	0.004					0.009	85.0	0.5	
Bus381	11.000		0.015	0.009	0.048	0.030					0.147	85.0	8.7	
Bus383	11.000		0.015	0.009	0.047	0.029					0.072	85.0	4.3	
Bus385	11.000										0.664	85.1	39.5	
Bus387	11.000		0.038	0.024	0.119	0.074					0.185	85.0	11.0	
Bus389	11.000										0.478	85.1	28.5	
Bus391	11.000		0.008	0.005	0.025	0.016					0.039	85.0	2.3	
Bus393	11.000		0.014	0.008	0.042	0.026					0.439	85.1	26.1	
Bus397	11.000										0.373	85.1	22.2	
Bus399	11.000		0.009	0.006	0.029	0.018					0.045	85.0	2.7	
Bus401	11.000										0.327	85.0	19.5	
Bus403	11.000		0.048	0.030	0.147	0.091					0.229	85.0	13.7	
Bus405	11.000										0.098	85.1	5.9	
Bus407	11.000										0.098	85.1	5.9	
Bus409	11.000		0.019	0.012	0.058	0.036					0.090	85.0	5.4	
Bus411	11.000										0.008	85.0	0.5	
Bus413	11.000		0.002	0.001	0.005	0.003					0.008	85.0	0.5	
Bus415	11.000		0.014	0.009	0.043	0.027					2.217	84.9	131.9	
Bus417	11.000		0.015	0.009	0.047	0.029					2.129	85.0	128.0	
Bus419	11.000										2.047	85.0	123.6	
Bus421	11.000		0.026	0.016	0.077	0.048					0.295	85.0	17.8	
Bus423	11.000		0.037	0.023	0.112	0.069					0.175	85.0	10.6	
Bus425	11.000		0.042	0.026	0.125	0.077					1.744	85.0	105.7	
Bus427	11.000		0.329	0.204	0.987	0.612					1.548	85.0	93.9	
Bus428	11.000		0.107	0.066	0.399	0.247					2.372	85.0	129.0	
Bus430	11.000		0.128	0.079	0.475	0.294					1.777	85.0	96.6	
Bus432	11.000		0.107	0.066	0.399	0.247					1.068	85.0	58.1	
Bus434	11.000		0.085	0.053	0.317	0.196					0.473	85.0	25.7	
Bus435	11.000		0.170	0.105	0.623	0.386					2.333	85.0	127.9	
Bus437	11.000		0.170	0.105	0.623	0.386					1.400	85.0	76.7	
Bus439	11.000		0.085	0.053	0.312	0.193					0.467	85.0	25.6	
Bus443	33.000										4.103	86.8	75.0	

Bus			Directly Connected Load								Total Bus Load			
			Constant kVA		Constant Z		Constant I		Generic					Percent
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Loading
Bus445	33.000		0.015	0.009	0.054	0.034					0.082	85.0	1.5	
Bus448	33.000		0.001	0.001	0.003	0.002					0.005	85.0	0.1	
Bus450	66.000										0.078	57.7	0.7	
Bus452	33.000										0.078	57.6	1.4	
Bus454	33.000		0.001	0.000	0.002	0.001					0.057	78.5	1.0	
Bus456	33.000										0.055	76.8	1.0	
Bus458	33.000		0.008	0.005	0.034	0.021					0.050	85.0	0.9	
Bus463	11.000		0.051	0.032	0.168	0.104					0.258	85.0	14.9	
Bus464	33.000													
Bus465	33.000												-	
Bus807	33.000		0.032	0.020	0.031	0.019					0.073	85.0	1.3	
Bus809	33.000										1.703	92.0	30.5	
Bus810	33.000		0.010	0.006	0.009	0.006					0.023	85.0	0.4	
Bus811	33.000		0.085	0.053	0.081	0.050					0.196	85.0	3.5	
Bus813	33.000		0.014	0.009	0.014	0.009					1.488	92.8	26.7	
Bus814	33.000		0.005	0.003	0.005	0.003					0.012	85.0	0.2	
Bus933	11.000										4.297	85.3	248.3	
Bus934	33.000		0.017	0.011	0.064	0.040					4.675	82.5	84.5	
Bus946	33.000										4.691	82.5	84.5	
Bus947	33.000										4.675	82.5	84.5	
Bus948	33.000										4.515	82.3	83.0	
Bus950	33.000										4.515	82.3	83.0	
Bus951	33.000		0.008	0.005	0.031	0.019					0.047	85.0	0.9	
Bus953	33.000										13.121	82.5	243.5	
Bus954	33.000										13.301	82.4	243.4	
Bus956	11.000										4.840	85.0	284.6	
Bus958	11.000										3.495	85.1	202.1	
Bus960	33.000										4.362	83.5	81.3	
Bus961	33.000										4.362	83.5	81.3	
Bus963	11.000										2.629	85.0	151.3	
Bus964	11.000										1.630	85.2	92.7	
Bus965	66.000										6.840	84.7	59.8	
Bus966	33.000										4.294	87.3	76.7	
Bus967	33.000										2.427	83.5	43.0	
Bus971	11.000										2.372	85.0	129.0	
Bus972	11.000										2.333	85.0	127.9	
Bus973	11.000		0.000	0.000	0.001	0.001					1.440	85.3	83.6	
Bus975	11.000		0.058	0.036	0.183	0.113					1.413	85.1	83.5	
Bus977	11.000		0.067	0.042	0.212	0.131					1.130	85.2	66.8	
Bus979	11.000		0.026	0.016	0.082	0.051					0.797	85.2	47.4	
Bus980	11.000										0.119	85.0	7.1	
Bus981	11.000		0.025	0.015	0.077	0.048					0.119	85.0	7.1	

Bus			Directly Connected Load								Total Bus Load			
			Constant kVA		Constant Z		Constant I		Generic					Percent
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Loading
Bus983	11.000		0.068	0.042	0.209	0.130					0.546	85.2	32.7	
Bus985	11.000		0.003	0.002	0.009	0.006					0.220	85.4	13.2	
Bus987	11.000										0.205	85.4	12.3	
Bus989	11.000		0.010	0.006	0.030	0.019					0.063	85.1	3.8	
Bus991	11.000		0.003	0.002	0.010	0.006					0.016	85.0	1.0	
Bus993	11.000		0.027	0.017	0.083	0.051					0.142	85.4	8.5	
Bus995	11.000										0.012	86.6	0.7	
Bus996	11.000		0.000	0.000	0.001	-					0.001	85.0	0.1	
Bus997	11.000		0.002	0.002	0.007	0.005					0.012	85.0	0.7	
Bus998	11.000		0.000	0.000	0.001	-					0.001	85.0	0.1	
Bus999	11.000										0.493	85.5	28.5	
Bus1000	11.000		0.022	0.013	0.004	0.003					0.031	85.0	1.8	
Bus1002	11.000										0.377	85.4	21.9	
Bus1003	11.000		0.168	0.104	0.034	0.021					0.238	85.0	13.9	
Bus1004	11.000										0.238	85.0	13.9	
Bus1006	11.000		0.052	0.032	0.011	0.007					0.138	85.8	8.0	
Bus1008	11.000		0.003	0.002	0.001	-					0.064	86.5	3.7	
Bus1010	11.000										0.060	86.1	3.5	
Bus1011	11.000		0.001	0.000	0.000	-					0.001	85.0	0.1	
Bus1013	11.000		0.039	0.024	0.008	0.005					0.059	85.6	3.4	
Bus1014	11.000		0.003	0.002	0.001	-					0.005	85.0	0.3	
Bus1016	11.000		0.033	0.021	0.007	0.004					0.084	86.2	4.9	
Bus1018	11.000		0.007	0.004	0.001	0.001					0.037	87.4	2.1	
Bus1020	11.000		0.005	0.003	0.001	0.001					0.027	87.3	1.6	
Bus1022	11.000		0.003	0.002	0.001	-					0.020	87.3	1.2	
Bus1024	11.000										0.015	86.6	0.9	
Bus1025	11.000		0.009	0.005	0.002	0.001					0.013	85.0	0.7	
Bus1026	11.000		0.003	0.002							0.003	85.0	0.2	
Bus1027	11.000		0.004	0.003	0.003	0.002					2.082	85.4	121.4	
Bus1029	11.000										2.064	85.4	120.8	
Bus1030	11.000		0.046	0.029	0.037	0.023					0.098	85.0	5.7	
Bus1032	11.000										1.961	85.4	115.1	
Bus1033	11.000		0.187	0.116	0.149	0.093					0.396	85.0	23.2	
Bus1034	11.000										0.396	85.0	23.2	
Bus1036	11.000		0.028	0.017	0.022	0.013					1.550	85.5	91.9	
Bus1038	11.000		0.036	0.022	0.027	0.017					1.476	85.4	88.5	
Bus1040	11.000										1.391	85.4	84.0	
Bus1041	11.000		0.003	0.002	0.002	0.001					0.007	85.0	0.4	
Bus1043	11.000										1.372	85.3	83.6	
Bus1045	11.000		0.009	0.005	0.006	0.004					0.017	85.0	1.1	
Bus1047	11.000		0.015	0.010	0.011	0.007					1.354	85.3	82.6	
Bus1049	11.000		0.007	0.004	0.005	0.003					1.302	85.2	80.7	

Bus			Directly Connected Load								Total Bus Load			
			Constant kVA		Constant Z		Constant I		Generic					
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Percent Loading
Bus1051	11.000										1.278	85.2	79.8	
Bus1052	11.000		0.040	0.025	0.028	0.017					0.080	85.0	5.0	
Bus1054	11.000		0.011	0.007	0.007	0.005					1.190	85.1	74.8	
Bus1056	11.000										0.545	85.2	34.4	
Bus1058	11.000		0.003	0.002	0.002	0.001					0.542	85.2	34.4	
Bus1059	11.000		0.024	0.015	0.016	0.010					0.047	85.0	3.0	
Bus1060	11.000		0.000	0.000	0.000	-					0.001	85.0	-	
Bus1062	11.000		0.100	0.062	0.068	0.042					0.487	85.1	31.0	
Bus1064	11.000										0.289	85.1	18.4	
Bus1066	11.000										0.132	85.0	8.4	
Bus1067	11.000		0.026	0.016	0.017	0.011					0.050	85.0	3.2	
Bus1068	11.000		0.041	0.026	0.028	0.017					0.082	85.0	5.2	
Bus1070	11.000		0.044	0.027	0.029	0.018					0.157	85.0	10.0	
Bus1072	11.000		0.009	0.005	0.006	0.004					0.071	85.0	4.5	
Bus1073	11.000		0.028	0.017	0.019	0.012					0.054	85.0	3.5	
Bus1075	11.000										0.621	85.0	39.1	
Bus1077	11.000		0.149	0.092	0.103	0.064					0.567	85.0	35.8	
Bus1078	11.000		0.027	0.016	0.018	0.011					0.053	85.0	3.3	
Bus1079	11.000										0.567	85.0	35.8	
Bus1080	11.000		0.136	0.084	0.094	0.058					0.271	85.0	17.1	
Bus1081	11.000		0.011	0.007	0.022	0.014					0.221	85.2	12.8	
Bus1083	11.000		0.050	0.031	0.095	0.059					0.182	85.0	10.5	
Bus1084	11.000		0.003	0.002	0.006	0.004					0.012	85.0	0.7	
Bus1085	11.000		0.026	0.016	0.005	0.003					0.037	85.0	2.1	
Bus1086	11.000										3.096	85.0	182.0	
Bus1087	11.000		0.064	0.040	0.053	0.033					1.269	85.2	73.3	
Bus1088	11.000										1.274	85.2	73.3	
Bus1090	11.000		0.102	0.063	0.021	0.013					1.125	85.2	65.4	
Bus1091	11.000										1.130	85.2	65.4	
Bus1093	11.000										0.979	85.2	57.0	
Bus1094	11.000		0.015	0.009	0.012	0.007					0.032	85.0	1.8	
Bus1096	11.000		0.084	0.052	0.067	0.042					0.939	85.2	55.2	
Bus1098	11.000										0.755	85.1	44.7	
Bus1099	11.000		0.022	0.014	0.018	0.011					0.047	85.0	2.8	
Bus1101	11.000		0.032	0.020	0.025	0.015					0.707	85.1	41.9	
Bus1103	11.000										0.637	85.1	38.0	
Bus1104	11.000		0.085	0.053	0.260	0.161					0.406	85.0	24.4	
Bus1106	11.000		0.073	0.045	0.057	0.035					0.228	85.0	13.6	
Bus1108	11.000		0.036	0.022	0.028	0.017					0.075	85.0	4.5	

* Indicates operating load of a bus exceeds the bus critical limit (100.0% of the Continuous Ampere rating).
# Indicates operating load of a bus exceeds the bus marginal limit (95.0% of the Continuous Ampere rating).

Branch Loading Summary Report

CKT / Branch		Cable & Reactor			Transformer				
					Capability (MVA)	Loading (input)		Loading (output)	
ID	Type	Ampacity (Amp)	Loading Amp	%		MVA	%	MVA	%
Cable1	Cable	261.41	46.11	17.64					
Cable2	Cable	190.58	82.72	43.40					
Cable3	Cable	147.19	24.51	16.65					
Cable4	Cable	212.74	76.11	35.77					
Cable5	Cable	261.41	23.05	8.82					
Cable6	Cable	190.58	76.11	39.93					
Cable7	Cable	229.86	6.32	2.75					
Cable8	Cable	147.19	2.06	1.40					
Cable10	Cable	270.43	22.41	8.29					
Cable11	Cable	229.86	5.67	2.47					
Cable13	Cable	229.86	30.41	13.23					
Cable14	Cable	270.43	147.56	54.57					
Cable15	Cable	338.03	23.90	7.07					
Cable16	Cable	270.43	3.05	1.13					
Cable18	Cable	270.43	3.06	1.13					
Cable19	Cable	229.86	17.03	7.41					
Cable20	Cable	147.19	2.00	1.36					
Cable21	Cable	270.43	121.47	44.92					
Cable25	Cable	270.43	0.31	0.11					
Cable27	Cable	270.43	71.91	26.59					
Cable29	Cable	147.19	36.56	24.84					
Cable30	Cable	229.86	187.21	81.45					
Cable32	Cable	229.86	0.49	0.21					
Cable34	Cable	229.86	93.86	40.83					
Cable35	Cable	338.03	129.01	38.16					
Cable37	Cable	338.03	96.63	28.59					
Cable39	Cable	338.03	58.08	17.18					
Cable41	Cable	338.03	25.70	7.60					
Cable42	Cable	338.03	127.90	37.84					
Cable44	Cable	338.03	76.74	22.70					
Cable46	Cable	338.03	25.58	7.57					
Cable47	Cable	274.79							
Cable48	Cable	200.71	14.90	7.43					

CKT / Branch		Cable & Reactor			Transformer				
					Capability (MVA)	Loading (input)		Loading (output)	
ID	Type	Ampacity (Amp)	Loading Amp	%		MVA	%	MVA	%
Cable88	Cable	190.58	84.46	44.32					
Cable90	Cable	274.79	84.51	30.76					
Cable92	Cable	274.79	83.02	30.21					
Cable93	Cable	190.58	0.85	0.45					
* Cable95	Cable	190.58	243.39	127.71					
Cable97	Cable	190.58	81.32	42.67					
Cable98	Cable	229.86	13.85	6.03					
Cable99	Cable	147.19	23.24	15.79					
Cable101	Cable	229.86	35.76	15.56					
Cable102	Cable	147.19	2.12	1.44					
Cable103	Cable	270.43	182.03	67.31					
Cable105	Cable	270.43	12.06	4.46					
Cable107	Cable	338.03	73.31	21.69					
33/11kV PangbesaT1	Transformer				5.000	2.427	48.5	2.372	47.4
33/11kV PangbesaT2	Transformer				5.000	2.386	47.7	2.333	46.7
66/33 Pangbesa T1	Transformer				10.000	2.458	24.6	2.427	24.3
66/33kV Jemina Trf	Transformer				5.000	0.078	1.6	0.078	1.6
66/33kV PangbesaT2	Transformer				10.000	4.385	43.8	4.294	42.9
Jangsa T1	Transformer				5.000	2.705	54.1	2.629	52.6
Jangsa T2	Transformer				5.000	1.658	33.2	1.630	32.6
Jitshephu Trf1	Transformer				2.500	1.841	73.6	1.778	71.1
Jitshephu Trf2	Transformer				2.500	1.841	73.6	1.778	71.1
Olathang Trf.1	Transformer				20.000	9.548	47.7	9.279	46.4
Olathang Trf2	Transformer				20.000	13.961	69.8	13.347	66.7
Shaba Transformer	Transformer				5.000	4.502	90.0	4.297	85.9
* Tshongdu T1	Transformer				5.000	5.112	102.2	4.840	96.8
Tshongdu T2	Transformer				5.000	3.631	72.6	3.495	69.9

* Indicates a branch with operating load exceeding the branch capability.

Branch Losses Summary Report

Branch ID	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
Olathang Trf.1	7.879	5.392	-7.857	-4.937	22.8	455.2	100.0	97.2	2.82
Olathang Trf2	11.047	8.536	-10.998	-7.563	48.7	973.3	100.0	95.6	4.39
Cable2	3.986	2.285	-3.986	-2.285	0.0	0.0	97.2	97.2	0.00
Cable88	3.870	2.652	-3.870	-2.652	0.0	0.0	97.2	97.2	0.00
Cable93	0.040	0.025	-0.040	-0.025	0.0	0.0	95.6	95.6	0.00
Cable95	10.958	7.539	-10.958	-7.539	0.0	0.0	95.6	95.6	0.00
Line1	-0.666	-0.406	0.669	0.408	2.5	1.9	91.9	92.3	0.39
Line4	0.569	0.346	-0.568	-0.345	1.5	1.0	91.9	91.6	0.27
Line3	-0.012	-0.007	0.012	0.006	0.0	-1.6	95.2	95.2	0.00
Line7	0.531	0.322	-0.530	-0.321	1.2	0.8	91.6	91.4	0.24
117	0.437	-0.068	-0.437	0.060	0.1	-7.9	95.5	95.5	0.02
Line28	-3.489	-1.992	3.494	1.995	5.3	2.9	95.5	95.7	0.20
Jitshephu Trf1	1.526	1.030	-1.511	-0.938	15.3	91.7	95.5	92.2	3.25
Jitshephu Trf2	1.526	1.030	-1.511	-0.938	15.3	91.7	95.5	92.2	3.25
Line156	0.581	0.359	-0.580	-0.359	1.0	0.4	92.2	92.1	0.15
Line166	2.109	1.314	-2.109	-1.314	0.5	0.4	92.2	92.2	0.02
Cable16	0.046	0.028	-0.046	-0.028	0.0	0.0	92.2	92.2	0.00
Cable19	0.255	0.156	-0.255	-0.156	0.0	0.0	92.2	92.2	0.00
Cable20	0.030	0.019	-0.030	-0.019	0.0	0.0	92.2	92.2	0.00
Line5	-0.810	-0.499	0.813	0.501	3.3	1.4	88.5	88.8	0.34
Line9	0.095	0.059	-0.095	-0.059	0.0	0.0	88.5	88.5	0.01
Line17	0.715	0.441	-0.715	-0.440	0.5	0.2	88.5	88.4	0.06
Line2	3.986	2.285	-3.974	-2.276	12.0	8.6	97.2	96.8	0.40
Line11	0.043	0.026	-0.043	-0.027	0.0	-0.2	91.4	91.4	0.02
Line19	0.486	0.294	-0.485	-0.294	0.5	0.3	91.4	91.3	0.10
Line6	0.040	0.016	-0.040	-0.025	0.0	-8.6	96.8	96.8	0.00
Line8	3.934	2.260	-3.933	-2.259	1.0	0.7	96.8	96.7	0.03
Line15	0.038	0.024	-0.038	-0.024	0.0	-0.1	91.4	91.3	0.01
Line16	0.005	0.003	-0.005	-0.003	0.0	-0.2	91.4	91.3	0.00
Line10	3.855	2.211	-3.850	-2.208	4.5	3.1	96.7	96.6	0.16
Line12	3.795	2.173	-3.786	-2.167	9.2	6.0	96.6	96.3	0.32
Line14	0.103	0.064	-0.103	-0.064	0.0	-0.3	96.3	96.3	0.00
Line18	3.682	2.104	-3.682	-2.103	0.7	0.3	96.3	96.3	0.02
Line23	0.425	0.257	-0.424	-0.256	1.1	0.6	91.3	91.0	0.27

	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
Branch ID	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
Line20	3.634	2.074	-3.628	-2.070	5.8	3.5	96.3	96.0	0.21
Line25	0.323	0.200	-0.323	-0.200	0.1	0.0	88.4	88.4	0.03
Line33	0.392	0.240	-0.392	-0.240	0.5	0.2	88.4	88.3	0.11
Line22	0.002	0.000	-0.002	-0.001	0.0	-1.3	96.0	96.0	0.00
Line24	3.625	2.070	-3.618	-2.065	7.9	4.7	96.0	95.8	0.29
Cable4	3.618	2.065	-3.618	-2.065	0.0	0.0	95.8	95.8	0.00
Cable6	3.618	2.065	-3.618	-2.065	0.0	0.0	95.8	95.8	0.00
Line27	0.163	0.100	-0.163	-0.100	0.0	0.0	91.0	91.0	0.01
Line45	0.261	0.156	-0.261	-0.156	0.4	0.0	91.0	90.8	0.15
Line26	0.052	0.030	-0.052	-0.032	0.0	-2.2	95.8	95.8	0.00
Line390	3.566	2.035	-3.564	-2.034	2.2	1.3	95.8	95.7	0.08
Line30	0.046	0.021	-0.046	-0.023	0.0	-1.8	95.5	95.5	0.00
Line34	0.391	-0.081	-0.391	0.072	0.2	-9.4	95.5	95.4	0.04
Line31	0.063	0.038	-0.063	-0.038	0.0	0.0	91.0	91.0	0.00
Line32	0.006	-0.001	-0.006	-0.004	0.0	-5.4	95.5	95.5	0.00
Line35	0.035	0.021	-0.035	-0.021	0.0	-0.2	91.0	91.0	0.03
Line36	0.383	-0.077	-0.382	0.074	0.1	-2.3	95.4	95.4	0.02
Line38	0.008	-0.009	-0.008	0.002	0.0	-7.1	95.4	95.4	0.00
Line42	0.347	-0.083	-0.347	0.079	0.1	-3.8	95.4	95.4	0.01
Line39	0.033	0.020	-0.033	-0.020	0.0	-0.1	91.0	91.0	0.01
Line41	0.002	0.001	-0.002	-0.001	0.0	-0.6	91.0	91.0	0.00
Line40	0.004	-0.004	-0.004	-0.002	0.0	-6.6	95.4	95.4	0.00
Line44	0.311	-0.101	-0.311	0.097	0.1	-3.9	95.4	95.4	0.01
Line46	0.035	0.022	-0.035	-0.022	0.0	-0.2	95.4	95.4	0.00
Line48	0.276	-0.119	-0.276	0.108	0.1	-11.1	95.4	95.3	0.02
Line43	0.095	0.059	-0.094	-0.059	0.0	-0.1	88.3	88.3	0.02
Line51	0.241	0.149	-0.241	-0.149	0.2	0.0	88.3	88.2	0.07
Line72	0.056	0.033	-0.056	-0.033	0.1	-0.6	88.3	88.2	0.12
Line50	0.261	-0.116	-0.261	0.110	0.1	-6.1	95.3	95.3	0.03
Line49	0.018	0.011	-0.018	-0.011	0.0	0.0	90.8	90.8	0.00
Line53	0.243	0.145	-0.242	-0.145	0.3	0.0	90.8	90.7	0.13
Line52	0.253	-0.115	-0.253	0.109	0.1	-6.3	95.3	95.3	0.03
Line57	0.253	-0.109	-0.253	0.109	0.0	-0.4	95.3	95.3	0.00
Line59	0.201	-0.141	-0.201	0.133	0.1	-7.7	95.3	95.3	0.01
Line56	0.203	0.121	-0.203	-0.121	0.1	-0.1	90.7	90.7	0.05
Line61	0.189	-0.141	-0.189	0.125	0.1	-15.7	95.3	95.3	0.01
Line63	0.188	-0.125	-0.188	0.121	0.0	-4.4	95.3	95.3	0.00

Branch ID	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
Line60	0.146	0.086	-0.146	-0.086	0.1	-0.1	90.7	90.6	0.04
Line65	0.021	-0.031	-0.021	0.023	0.0	-8.3	95.3	95.3	0.00
Line80	0.014	-0.034	-0.014	0.014	0.0	-20.4	95.3	95.3	0.00
Line92	0.153	-0.055	-0.153	0.052	0.0	-3.5	95.3	95.3	0.00
Line68	0.020	-0.024	-0.020	0.018	0.0	-6.5	95.3	95.3	0.00
Line64	0.016	0.009	-0.016	-0.009	0.0	0.0	90.6	90.6	0.00
Line77	0.101	0.059	-0.100	-0.059	0.1	-0.3	90.6	90.5	0.10
Line70	0.005	-0.005	-0.005	-0.003	0.0	-7.9	95.3	95.3	0.00
Line74	0.015	-0.013	-0.015	0.009	0.0	-4.1	95.3	95.3	0.00
Line58	0.071	0.044	-0.071	-0.044	0.0	0.0	88.2	88.2	0.00
Line67	0.001	0.000	-0.001	-0.001	0.0	-0.4	90.6	90.6	0.00
Line71	0.014	0.008	-0.014	-0.008	0.0	-0.1	90.6	90.6	0.00
Line76	0.013	-0.010	-0.013	0.003	0.0	-6.2	95.3	95.3	0.00
Line78	0.006	-0.008	-0.006	-0.004	0.0	-11.7	95.3	95.3	0.00
Line73	0.008	0.004	-0.008	-0.005	0.0	-0.6	90.6	90.6	0.02
Line82	0.007	-0.004	-0.007	-0.004	0.0	-8.0	95.3	95.3	0.00
Line84	0.007	-0.010	-0.007	0.001	0.0	-8.7	95.3	95.3	0.00
Line66	0.013	0.008	-0.013	-0.008	0.0	-0.2	88.2	88.2	0.01
Line86	0.004	0.001	-0.004	-0.002	0.0	-1.4	95.3	95.3	0.00
Line88	0.003	-0.002	-0.003	-0.002	0.0	-4.4	95.3	95.3	0.00
Line94	0.152	-0.052	-0.152	0.046	0.0	-6.5	95.3	95.2	0.01
Line96	0.150	-0.047	-0.150	0.042	0.0	-4.7	95.2	95.2	0.01
Line81	0.090	0.053	-0.090	-0.053	0.0	0.0	90.5	90.5	0.01
Line98	0.004	-0.017	-0.004	0.007	0.0	-10.3	95.2	95.2	0.00
Line102	0.146	-0.025	-0.146	0.016	0.0	-9.5	95.2	95.2	0.01
Line100	0.002	-0.008	-0.002	-0.001	0.0	-9.0	95.2	95.2	0.00
Line85	0.073	0.045	-0.073	-0.045	0.0	-0.2	90.5	90.5	0.06
Line89	0.004	0.002	-0.004	-0.003	0.0	-0.4	90.5	90.5	0.01
Line93	0.013	0.005	-0.013	-0.006	0.0	-0.4	90.5	90.5	0.01
Line104	0.141	-0.019	-0.141	0.015	0.0	-3.4	95.2	95.2	0.01
Line106	0.139	-0.017	-0.139	0.012	0.0	-4.8	95.2	95.2	0.01
Line108	0.136	-0.014	-0.136	0.010	0.0	-3.6	95.2	95.2	0.01
Line110	0.118	-0.021	-0.118	0.013	0.0	-7.9	95.2	95.2	0.01
Line97	0.002	0.000	-0.002	-0.001	0.0	-0.5	90.5	90.5	0.00
Line101	0.012	0.005	-0.012	-0.006	0.0	-0.2	90.5	90.5	0.01
Line112	0.113	-0.017	-0.113	-0.016	0.1	-33.1	95.2	95.1	0.05
Line114	0.002	-0.001	-0.002	-0.001	0.0	-2.0	95.1	95.1	0.00

Branch ID	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
Line117	0.111	0.018	-0.111	-0.019	0.0	-1.7	95.1	95.1	0.00
Line79	0.025	0.014	-0.025	-0.015	0.0	-1.4	88.2	88.1	0.12
Line119	0.002	-0.003	-0.002	-0.001	0.0	-4.4	95.1	95.1	0.00
Line121	0.109	0.022	-0.109	-0.030	0.0	-7.5	95.1	95.1	0.01
Line105	0.003	0.002	-0.003	-0.002	0.0	-0.1	90.5	90.5	0.00
Line109	0.009	0.004	-0.009	-0.004	0.0	-0.1	90.5	90.5	0.00
Line123	0.013	0.007	-0.013	-0.008	0.0	-0.9	95.1	95.1	0.00
Line125	0.096	0.023	-0.096	-0.023	0.0	-0.6	95.1	95.1	0.00
Line127	0.089	0.019	-0.089	-0.020	0.0	-0.6	95.1	95.1	0.00
Line129	0.089	0.019	-0.089	-0.020	0.0	-0.5	95.1	95.1	0.00
Line113	0.006	0.002	-0.006	-0.004	0.0	-1.4	90.5	90.5	0.02
Line131	0.061	0.007	-0.061	-0.017	0.0	-10.3	95.1	95.1	0.01
Line149	0.027	0.013	-0.027	-0.014	0.0	-1.0	95.1	95.1	0.00
Line133	0.028	0.011	-0.028	-0.015	0.0	-4.8	95.1	95.1	0.00
Line143	0.033	0.007	-0.033	-0.012	0.0	-5.3	95.1	95.1	0.00
Cable1	-0.689	-0.427	0.689	0.427	0.0	0.0	92.3	92.3	0.00
Cable5	0.344	0.213	-0.344	-0.213	0.0	0.0	92.3	92.3	0.00
Line135	0.002	0.001	-0.002	-0.001	0.0	-0.8	95.1	95.1	0.00
Line139	0.026	0.015	-0.026	-0.015	0.0	-0.6	95.1	95.1	0.00
Cable8	-0.031	-0.019	0.031	0.019	0.0	0.0	92.3	92.3	0.00
Line115	-1.130	-0.696	1.148	0.720	17.8	24.1	89.3	91.2	1.92
Line118	0.013	0.008	-0.013	-0.008	0.0	0.0	89.3	89.3	0.00
Line122	0.071	0.044	-0.071	-0.044	0.1	-0.2	89.3	89.2	0.06
Line126	1.046	0.644	-1.034	-0.639	11.9	5.3	89.3	88.4	0.95
Line141	0.013	0.008	-0.013	-0.008	0.0	-0.7	95.1	95.1	0.00
Line145	0.014	0.000	-0.014	-0.001	0.0	-1.0	95.1	95.1	0.00
Line147	0.001	-0.007	-0.001	0.000	0.0	-7.7	95.1	95.1	0.00
Line151	0.004	0.000	-0.004	-0.002	0.0	-2.4	95.1	95.1	0.00
Line153	0.024	0.014	-0.024	-0.014	0.0	-0.3	95.1	95.1	0.00
Line155	0.011	0.006	-0.011	-0.007	0.0	-0.4	95.1	95.1	0.00
Line157	0.377	0.233	-0.377	-0.233	0.2	0.1	92.1	92.0	0.05
Line130	0.943	0.583	-0.941	-0.582	2.5	1.1	88.4	88.1	0.22
Line159	0.021	0.013	-0.021	-0.013	0.0	-0.1	92.0	92.0	0.01
Line161	0.356	0.220	-0.356	-0.220	0.4	0.2	92.0	91.9	0.14
Line83	-1.473	-0.911	1.482	0.919	9.2	7.8	88.6	89.3	0.62
Line91	0.352	0.218	-0.351	-0.218	0.5	0.2	88.6	88.5	0.15
Line99	1.121	0.693	-1.121	-0.693	0.3	0.2	88.6	88.6	0.03

Branch ID	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
Line163	0.318	0.196	-0.317	-0.196	1.0	0.2	91.9	91.6	0.28
Line134	0.831	0.514	-0.830	-0.513	1.5	0.6	88.1	88.0	0.15
Line165	0.234	0.145	-0.234	-0.145	0.1	0.0	91.6	91.6	0.04
Line168	1.934	1.205	-1.891	-1.168	43.2	37.2	92.2	89.9	2.29
Cable3	0.351	0.218	-0.351	-0.218	0.0	0.0	88.5	88.5	0.00
Cable7	0.092	0.057	-0.092	-0.057	0.0	0.0	89.9	89.9	0.00
Line170	1.799	1.111	-1.794	-1.107	5.2	4.5	89.9	89.6	0.29
Line137	0.830	0.513	-0.828	-0.512	1.6	0.7	88.0	87.8	0.16
Line171	0.204	0.127	-0.204	-0.127	0.0	0.0	89.6	89.6	0.01
Line173	1.589	0.980	-1.586	-0.978	3.1	2.6	89.6	89.4	0.19
Line175	0.119	0.074	-0.119	-0.074	0.0	0.0	89.4	89.4	0.00
Line177	1.467	0.904	-1.460	-0.901	6.9	3.2	89.4	89.0	0.39
Line140	0.343	0.212	-0.342	-0.211	1.3	0.3	87.8	87.5	0.31
Line179	1.273	0.784	-1.265	-0.781	7.5	3.4	89.0	88.5	0.49
Cable11	0.081	0.050	-0.081	-0.050	0.0	0.0	88.5	88.5	0.00
Line181	1.184	0.731	-1.182	-0.730	2.0	0.9	88.5	88.4	0.14
Line144	0.276	0.170	-0.276	-0.170	0.5	0.1	87.5	87.4	0.15
Line183	0.318	0.197	-0.318	-0.197	0.0	0.0	88.4	88.4	0.01
Line184	0.072	0.044	-0.072	-0.045	0.0	-0.1	88.4	88.4	0.02
Line186	0.792	0.488	-0.789	-0.487	2.9	1.3	88.4	88.1	0.31
Line107	1.005	0.621	-1.002	-0.619	2.4	2.0	88.6	88.4	0.23
Line188	0.615	0.379	-0.609	-0.376	6.0	2.4	88.1	87.3	0.80
Line148	0.217	0.134	-0.217	-0.134	0.5	0.0	87.4	87.2	0.20
Cable13	0.430	0.266	-0.430	-0.266	0.0	0.0	87.3	87.3	0.00
Line202	0.116	0.071	-0.116	-0.071	0.0	0.0	87.3	87.3	0.02
Line190	0.417	0.258	-0.417	-0.258	0.1	0.0	87.3	87.3	0.02
Cable15	0.338	0.209	-0.338	-0.209	0.0	0.0	87.3	87.3	0.00
Line192	0.079	0.049	-0.079	-0.049	0.0	0.0	87.3	87.3	0.00
Line194	0.113	0.070	-0.113	-0.070	0.0	0.0	87.3	87.3	0.00
Line196	0.225	0.139	-0.224	-0.139	0.3	0.0	87.3	87.2	0.10
Line162	1.348	0.544	-1.348	-0.545	0.0	-0.3	97.3	97.3	0.00
Line187	-1.348	-0.544	1.353	0.537	5.1	-7.5	97.3	97.7	0.38
Line198	0.082	0.051	-0.082	-0.051	0.0	0.0	87.2	87.2	0.02
Line200	0.082	0.051	-0.082	-0.051	0.1	-0.3	87.2	87.1	0.09
Line204	0.041	0.025	-0.041	-0.025	0.0	-0.2	87.3	87.3	0.03
Line205	0.046	0.028	-0.046	-0.028	0.0	-0.3	92.2	92.2	0.02
Cable18	0.046	0.028	-0.046	-0.028	0.0	0.0	92.2	92.2	0.00

Branch ID	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
Line206	0.192	0.117	-0.192	-0.117	0.6	-0.2	92.2	91.9	0.27
Line199	1.313	0.523	-1.312	-0.529	1.0	-6.3	97.3	97.2	0.10
Line208	0.116	0.071	-0.116	-0.071	0.3	-0.4	91.9	91.8	0.19
Line210	0.034	0.020	-0.034	-0.021	0.0	-0.5	91.8	91.7	0.05
Line212	0.031	0.019	-0.031	-0.019	0.0	-0.3	91.7	91.7	0.03
Line154	-1.756	-0.780	1.758	0.778	1.6	-2.4	97.8	97.9	0.10
Line191	0.062	0.038	-0.062	-0.039	0.0	-0.3	97.8	97.8	0.00
Line742	1.569	0.664	-1.568	-0.666	1.2	-1.2	97.8	97.8	0.08
Line203	-1.311	-0.530	1.312	0.529	0.4	-0.7	97.2	97.2	0.03
Line209	0.025	0.013	-0.025	-0.015	0.0	-2.1	97.2	97.2	0.00
Line213	1.286	0.516	-1.285	-0.519	1.6	-2.6	97.2	97.0	0.12
Line217	0.050	0.031	-0.050	-0.031	0.0	-0.4	97.0	97.0	0.00
Line219	1.234	0.488	-1.234	-0.490	0.4	-1.6	97.0	97.0	0.04
Line221	0.136	-0.061	-0.136	-0.070	0.6	-131.0	97.0	96.6	0.44
Line229	1.098	0.551	-1.097	-0.553	0.5	-2.2	97.0	97.0	0.05
Line223	0.031	0.019	-0.031	-0.019	0.0	-0.2	96.6	96.6	0.00
Line225	0.105	0.051	-0.105	-0.054	0.0	-3.2	96.6	96.6	0.01
Line231	0.085	0.042	-0.085	-0.044	0.0	-1.8	96.6	96.5	0.00
Line235	0.054	0.034	-0.054	-0.034	0.0	-0.2	96.5	96.5	0.00
Line237	0.031	0.010	-0.031	-0.016	0.0	-6.2	96.5	96.5	0.01
Line239	0.015	0.007	-0.015	-0.009	0.0	-2.6	96.5	96.5	0.00
Line241	0.048	0.030	-0.048	-0.030	0.0	-0.5	97.0	97.0	0.00
Line243	1.049	0.523	-1.047	-0.533	1.8	-9.4	97.0	96.8	0.19
Line245	0.019	0.008	-0.019	-0.012	0.0	-4.2	96.8	96.8	0.00
Line247	1.028	0.525	-1.026	-0.537	1.2	-11.3	96.8	96.6	0.15
Line250	0.032	0.003	-0.032	-0.020	0.0	-16.4	96.6	96.6	0.01
Line252	0.995	0.533	-0.995	-0.534	0.0	-0.4	96.6	96.6	0.00
Line254	0.010	0.006	-0.010	-0.006	0.0	-0.1	96.6	96.6	0.00
Line256	0.956	0.509	-0.955	-0.510	0.0	-0.2	96.6	96.6	0.00
Line258	0.890	0.484	-0.890	-0.490	0.7	-5.3	96.6	96.5	0.09
Line259	0.065	0.025	-0.065	-0.028	0.0	-2.7	96.6	96.6	0.00
Line261	0.024	0.012	-0.024	-0.013	0.0	-1.1	96.6	96.6	0.00
Line265	0.041	0.016	-0.041	-0.020	0.0	-4.0	96.6	96.6	0.00
Line263	0.011	0.005	-0.011	-0.007	0.0	-1.9	96.6	96.6	0.00
Line267	0.026	0.011	-0.026	-0.013	0.0	-2.5	96.6	96.6	0.00
Line269	0.010	0.006	-0.010	-0.006	0.0	-0.3	96.6	96.6	0.00
Line270	0.017	0.008	-0.017	-0.010	0.0	-2.6	96.6	96.6	0.00

Branch ID	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
Line272	0.246	0.152	-0.246	-0.153	0.0	-0.6	96.5	96.5	0.00
Line274	0.561	0.287	-0.561	-0.288	0.0	-0.7	96.5	96.5	0.01
Line276	0.025	0.014	-0.025	-0.015	0.0	-1.3	96.5	96.5	0.00
Line278	0.537	0.274	-0.536	-0.284	0.5	-10.1	96.5	96.4	0.10
Line280	0.434	0.220	-0.433	-0.222	0.0	-1.7	96.4	96.4	0.01
Line282	0.401	0.202	-0.401	-0.203	0.0	-0.8	96.4	96.4	0.01
Line284	0.000	-0.002	0.000	0.000	0.0	-1.8	96.4	96.4	0.00
Line286	0.401	0.204	-0.401	-0.207	0.1	-2.4	96.4	96.4	0.02
Line288	0.381	0.195	-0.381	-0.199	0.1	-4.2	96.4	96.3	0.03
Line290	0.010	0.003	-0.010	-0.006	0.0	-2.6	96.3	96.3	0.00
Line295	0.371	0.195	-0.371	-0.197	0.0	-1.7	96.3	96.3	0.01
Line297	0.145	0.088	-0.145	-0.089	0.0	-1.7	96.3	96.3	0.00
Line303	0.202	0.094	-0.202	-0.099	0.0	-4.7	96.3	96.3	0.02
Line301	0.063	0.039	-0.063	-0.039	0.0	-0.4	96.3	96.3	0.00
Line305	0.005	-0.003	-0.005	-0.003	0.0	-5.8	96.3	96.3	0.00
Line307	0.166	0.082	-0.165	-0.085	0.0	-3.3	96.3	96.3	0.01
Line309	0.148	0.075	-0.148	-0.075	0.0	-0.4	96.3	96.3	0.00
Line311	0.017	0.007	-0.017	-0.010	0.0	-3.0	96.3	96.3	0.00
Line313	0.132	0.068	-0.132	-0.072	0.0	-3.7	96.3	96.3	0.01
Line315	0.094	0.048	-0.094	-0.050	0.0	-1.3	96.3	96.3	0.00
Line317	0.011	0.004	-0.011	-0.007	0.0	-2.3	96.3	96.3	0.00
Line319	0.083	0.045	-0.083	-0.046	0.0	-0.6	96.3	96.3	0.00
Line321	0.047	0.029	-0.047	-0.029	0.0	-0.3	96.3	96.3	0.00
Line325	0.036	0.017	-0.036	-0.020	0.0	-3.4	96.3	96.3	0.00
Line324	0.025	0.013	-0.025	-0.014	0.0	-0.9	96.3	96.3	0.00
Line327	0.025	0.014	-0.025	-0.015	0.0	-1.3	96.3	96.3	0.00
Cable105	-0.174	-0.108	0.174	0.108	0.0	0.0	89.3	89.3	0.00
Cable10	-0.324	-0.201	0.324	0.201	0.0	0.0	89.3	89.3	0.00
Cable14	-2.134	-1.320	2.134	1.320	0.0	0.0	89.3	89.3	0.00
Cable21	1.757	1.086	-1.757	-1.086	0.0	0.0	89.3	89.3	0.00
Cable25	0.004	0.003	-0.004	-0.003	0.0	0.0	89.3	89.3	0.00
Cable27	1.041	0.643	-1.041	-0.643	0.0	0.0	89.3	89.3	0.00
Line328	1.041	0.643	-1.036	-0.639	4.8	4.0	89.3	88.8	0.46
Line116	0.978	0.603	-0.975	-0.602	2.3	1.9	88.4	88.2	0.23
Line124	0.590	0.364	-0.586	-0.363	4.3	1.7	88.2	87.6	0.61
Line142	0.360	0.222	-0.359	-0.221	1.4	0.4	88.2	87.8	0.32
Cable29	0.518	0.321	-0.518	-0.321	0.0	0.0	87.6	87.6	0.00

Branch ID	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
Line132	0.016	0.009	-0.016	-0.010	0.0	-0.3	87.6	87.5	0.02
Line146	-0.324	-0.200	0.324	0.200	0.1	0.0	87.8	87.8	0.03
Line330	0.161	0.099	-0.161	-0.099	0.1	-0.1	87.8	87.7	0.08
Line336	0.163	0.101	-0.163	-0.101	0.1	-0.1	87.8	87.8	0.05
Line332	0.013	0.008	-0.013	-0.008	0.0	-0.4	87.7	87.7	0.01
Line334	0.006	0.003	-0.006	-0.003	0.0	-0.3	87.7	87.7	0.01
Line338	0.108	0.067	-0.107	-0.067	0.0	-0.1	87.8	87.7	0.02
Cable30	-2.755	-1.701	2.755	1.701	0.0	0.0	90.8	90.8	0.00
Line339	2.755	1.701	-2.683	-1.667	71.6	33.4	90.8	88.6	2.20
Line341	0.133	0.082	-0.132	-0.082	0.0	0.0	88.6	88.5	0.03
Line351	0.567	0.350	-0.565	-0.349	1.6	0.6	88.6	88.3	0.24
Line378	1.889	1.177	-1.882	-1.171	7.0	6.0	88.6	88.2	0.36
Line343	0.008	0.005	-0.008	-0.005	0.0	-0.2	88.5	88.5	0.01
Line345	0.125	0.077	-0.125	-0.077	0.1	-0.1	88.5	88.5	0.04
Line349	0.061	0.038	-0.061	-0.038	0.0	0.0	88.5	88.5	0.00
Line353	0.158	0.098	-0.157	-0.098	0.1	-0.1	88.3	88.3	0.06
Line355	0.407	0.252	-0.407	-0.251	0.9	0.3	88.3	88.1	0.19
Line357	0.033	0.021	-0.033	-0.021	0.0	0.0	88.1	88.1	0.00
Line359	0.373	0.231	-0.373	-0.231	0.3	0.1	88.1	88.1	0.08
Line363	0.317	0.196	-0.317	-0.196	0.2	0.1	88.1	88.0	0.06
Line365	0.038	0.024	-0.038	-0.024	0.0	-0.1	88.0	88.0	0.01
Line367	0.279	0.172	-0.278	-0.172	0.2	0.0	88.0	87.9	0.07
Line369	0.195	0.121	-0.195	-0.121	0.0	0.0	87.9	87.9	0.02
Line371	0.083	0.051	-0.083	-0.051	0.0	0.0	87.9	87.9	0.01
Line373	0.083	0.051	-0.083	-0.052	0.0	-0.1	87.9	87.9	0.03
Line375	0.076	0.047	-0.076	-0.047	0.0	0.0	87.9	87.9	0.00
Line376	0.007	0.004	-0.007	-0.004	0.0	-0.1	87.9	87.9	0.00
Cable32	0.007	0.004	-0.007	-0.004	0.0	0.0	87.9	87.9	0.00
Line380	1.825	1.136	-1.809	-1.122	16.3	14.1	88.2	87.3	0.88
Line382	1.747	1.083	-1.740	-1.077	7.1	6.1	87.3	86.9	0.39
Line384	0.251	0.156	-0.251	-0.156	0.0	0.0	86.9	86.9	0.01
Line388	1.489	0.922	-1.483	-0.919	6.2	2.8	86.9	86.6	0.34
Line386	0.149	0.092	-0.149	-0.092	0.0	0.0	86.9	86.9	0.01
Cable34	1.316	0.816	-1.316	-0.816	0.0	0.0	86.6	86.6	0.00
Cable35	-2.016	-1.250	2.016	1.250	0.0	0.0	96.5	96.5	0.00
Cable37	1.510	0.936	-1.510	-0.936	0.0	0.0	96.5	96.5	0.00
Cable39	0.908	0.563	-0.908	-0.563	0.0	0.0	96.5	96.5	0.00

Branch ID	From-To Bus Flow MW	From-To Bus Flow Mvar	To-From Bus Flow MW	To-From Bus Flow Mvar	Losses kW	Losses kvar	% Bus Voltage From	% Bus Voltage To	Vd % Drop in Vmag
Cable41	0.402	0.249	-0.402	-0.249	0.0	0.0	96.5	96.5	0.00
Cable42	-1.983	-1.229	1.983	1.229	0.0	0.0	95.7	95.7	0.00
Cable44	1.190	0.737	-1.190	-0.737	0.0	0.0	95.7	95.7	0.00
Cable46	0.397	0.246	-0.397	-0.246	0.0	0.0	95.7	95.7	0.00
Line392	0.069	0.039	-0.069	-0.043	0.0	-3.9	95.7	95.7	0.00
66/33kV Jemina Trf	0.045	-0.064	-0.045	0.064	0.0	0.1	100.0	100.1	0.08
Line393	0.045	-0.064	-0.045	0.034	0.0	-30.0	100.1	100.1	0.00
Line395	0.042	-0.036	-0.042	0.034	0.0	-1.1	100.1	100.1	0.00
Line397	0.042	0.001	-0.042	-0.026	0.0	-25.2	100.1	100.1	0.01
Line403	0.000	-0.035	0.000	0.000	0.0	-35.3	100.1	100.1	0.01
Line401	0.000	0.000	0.000	0.000	0.0	-0.2	100.1	100.1	0.00
Cable48	-0.219	-0.136	0.219	0.136	0.0	0.0	90.8	90.8	0.00
Cable47	0.000	0.000	0.000	0.000			100.1	100.1	
Line172	1.382	0.553	-1.381	-0.554	1.0	-1.4	97.8	97.7	0.07
Line174	0.166	0.101	-0.166	-0.103	0.0	-1.6	97.8	97.7	0.00
Line744	0.019	0.011	-0.019	-0.012	0.0	-0.8	97.8	97.7	0.00
Cable102	0.031	0.019	-0.031	-0.019	0.0	0.0	90.8	90.8	0.00
Line850	1.233	0.755	-1.228	-0.752	5.5	2.5	90.8	90.4	0.38
Line879	0.422	0.256	-0.421	-0.255	0.5	0.2	90.8	90.7	0.10
Line912	1.791	1.096	-1.778	-1.085	13.6	11.7	90.8	90.1	0.77
Line973	0.189	0.116	-0.188	-0.116	0.2	-0.1	90.8	90.7	0.10
Shaba Transformer	-3.666	-2.242	3.704	2.560	37.4	317.9	90.8	95.2	4.33
Cable90	-3.856	-2.645	3.856	2.645	0.0	0.0	96.8	96.8	0.00
Line846	3.774	2.594	-3.715	-2.566	58.5	28.4	96.8	95.2	1.63
Line844	3.870	2.652	-3.856	-2.645	14.6	7.2	97.2	96.8	0.40
Cable92	3.715	2.566	-3.715	-2.566	0.0	0.0	95.2	95.2	0.00
Line847	-10.819	-7.423	10.958	7.539	139.2	115.7	94.3	95.6	1.32
Line849	3.656	2.410	-3.641	-2.403	15.5	7.5	94.3	93.8	0.44
Tshongdu T1	4.164	2.965	-4.115	-2.548	49.1	417.5	94.3	89.3	5.02
Tshongdu T2	2.999	2.047	-2.974	-1.837	24.8	210.6	94.3	90.8	3.52
Cable103	2.633	1.629	-2.633	-1.629	0.0	0.0	89.3	89.3	0.00
Cable97	-3.641	-2.403	3.641	2.403	0.0	0.0	93.8	93.8	0.00
Jangsa T1	2.247	1.505	-2.233	-1.387	13.9	117.9	93.8	91.2	2.62
Jangsa T2	1.393	0.898	-1.388	-0.854	5.2	44.3	93.8	92.3	1.59
Cable107	1.086	0.667	-1.086	-0.667	0.0	0.0	91.2	91.2	0.00
66/33 Pangbesa T1	2.030	1.386	-2.026	-1.335	3.9	50.3	100.0	98.7	1.27
66/33kV PangbesaT2	3.763	2.251	-3.750	-2.091	12.3	160.0	100.0	97.9	2.07

Branch ID	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
33/11kV PangbesaT2	1.993	1.313	-1.983	-1.229	9.9	84.3	97.9	95.7	2.21
33/11kV PangbesaT1	2.026	1.335	-2.016	-1.250	10.1	85.8	98.7	96.5	2.23
Line852	1.226	0.751	-1.203	-0.741	22.8	10.3	90.4	88.9	1.57
Line854	0.963	0.592	-0.963	-0.592	0.1	0.0	88.9	88.9	0.01
Line856	0.683	0.419	-0.679	-0.417	4.2	1.8	88.9	88.3	0.51
Line858	0.102	0.062	-0.101	-0.063	0.2	-0.4	88.3	88.2	0.14
Line861	0.469	0.288	-0.465	-0.286	3.9	1.4	88.3	87.7	0.69
Line859	0.101	0.063	-0.101	-0.063	0.0	0.0	88.2	88.2	0.01
Line863	0.188	0.114	-0.188	-0.115	0.2	0.0	87.7	87.6	0.08
Line865	0.176	0.107	-0.175	-0.107	0.2	-0.1	87.6	87.5	0.10
Line867	0.054	0.033	-0.054	-0.033	0.0	-0.2	87.5	87.4	0.04
Line871	0.121	0.074	-0.121	-0.074	0.0	0.0	87.5	87.4	0.03
Line869	0.014	0.008	-0.014	-0.009	0.0	-0.2	87.4	87.4	0.01
Line873	0.011	0.006	-0.011	-0.006	0.0	-0.6	87.4	87.4	0.02
Line875	0.001	0.000	-0.001	-0.001	0.0	-0.2	87.4	87.4	0.00
Line877	0.010	0.006	-0.010	-0.006	0.0	-0.3	87.4	87.4	0.01
Line878	0.001	0.000	-0.001	-0.001	0.0	-0.2	87.4	87.4	0.00
Line881	0.026	0.016	-0.026	-0.016	0.0	-0.1	90.7	90.7	0.01
Line883	0.323	0.197	-0.322	-0.197	0.6	0.1	90.7	90.6	0.15
Line898	0.072	0.043	-0.072	-0.043	0.0	0.0	90.7	90.7	0.00
Line885	0.203	0.125	-0.203	-0.126	0.6	-0.1	90.6	90.3	0.26
Line887	0.119	0.071	-0.119	-0.071	0.0	0.0	90.6	90.6	0.01
Cable98	-0.203	-0.126	0.203	0.126	0.0	0.0	90.3	90.3	0.00
Line889	0.056	0.032	-0.056	-0.032	0.0	-0.3	90.6	90.5	0.05
Line891	0.052	0.030	-0.052	-0.030	0.0	-0.4	90.5	90.4	0.07
Line893	0.001	0.000	-0.001	-0.001	0.0	-0.8	90.4	90.4	0.00
Line894	0.051	0.031	-0.051	-0.031	0.0	-0.1	90.4	90.4	0.01
Line896	0.004	0.002	-0.004	-0.003	0.0	-0.8	90.4	90.4	0.01
Line900	0.032	0.018	-0.032	-0.018	0.0	-0.2	90.7	90.7	0.01
Line902	0.024	0.013	-0.024	-0.013	0.0	-0.6	90.7	90.7	0.04
Line904	0.017	0.009	-0.017	-0.010	0.0	-0.4	90.7	90.6	0.02
Line906	0.013	0.007	-0.013	-0.008	0.0	-0.5	90.6	90.6	0.02
Line908	0.011	0.007	-0.011	-0.007	0.0	0.0	90.6	90.6	0.00
Line911	0.003	0.001	-0.003	-0.002	0.0	-0.5	90.6	90.6	0.00
Line914	1.770	1.080	-1.762	-1.073	7.5	6.4	90.1	89.6	0.42
Line916	0.083	0.051	-0.083	-0.051	0.0	-0.1	89.6	89.6	0.03
Line918	1.679	1.022	-1.675	-1.020	4.5	2.1	89.6	89.4	0.22

Branch ID	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
Line920	0.336	0.208	-0.336	-0.208	0.2	0.1	89.4	89.4	0.05
Line922	1.338	0.811	-1.325	-0.805	13.6	6.2	89.4	88.6	0.85
Cable99	-0.336	-0.208	0.336	0.208	0.0	0.0	89.4	89.4	0.00
Line924	1.276	0.775	-1.261	-0.768	15.1	6.8	88.6	87.6	0.98
Line926	1.198	0.729	-1.188	-0.725	9.7	4.4	87.6	86.9	0.66
Line928	0.006	0.003	-0.006	-0.003	0.0	-0.1	86.9	86.9	0.00
Line930	1.182	0.721	-1.171	-0.716	11.8	5.3	86.9	86.1	0.81
Line932	0.015	0.009	-0.015	-0.009	0.0	-0.3	86.1	86.1	0.01
Line934	1.156	0.707	-1.155	-0.707	0.5	0.2	86.1	86.1	0.03
Line936	1.128	0.690	-1.110	-0.682	18.6	8.4	86.1	84.7	1.33
Line938	1.097	0.674	-1.089	-0.670	8.9	4.0	84.7	84.1	0.64
Line940	0.068	0.042	-0.068	-0.042	0.0	-0.1	84.1	84.1	0.03
Line942	1.020	0.628	-1.013	-0.624	7.8	3.5	84.1	83.5	0.60
Line944	0.466	0.286	-0.464	-0.285	1.6	0.6	83.5	83.2	0.28
Line966	0.529	0.327	-0.527	-0.327	1.1	0.5	83.5	83.3	0.17
Line946	0.464	0.285	-0.462	-0.284	2.4	0.9	83.2	82.8	0.40
Line948	0.040	0.025	-0.040	-0.025	0.0	-0.3	82.8	82.8	0.05
Line949	0.000	0.000	0.000	0.000	0.0	-0.4	82.8	82.8	0.00
Line951	0.416	0.257	-0.414	-0.256	2.4	0.9	82.8	82.4	0.44
Line953	0.246	0.152	-0.246	-0.152	0.3	0.0	82.4	82.3	0.08
Line955	0.112	0.069	-0.112	-0.069	0.1	-0.1	82.3	82.2	0.04
Line960	0.134	0.082	-0.133	-0.083	0.3	-0.2	82.3	82.1	0.18
Line957	0.043	0.026	-0.043	-0.026	0.0	0.0	82.2	82.2	0.00
Line958	0.069	0.043	-0.069	-0.043	0.0	0.0	82.2	82.2	0.01
Line962	0.060	0.037	-0.060	-0.037	0.0	-0.1	82.1	82.1	0.02
Line964	0.046	0.029	-0.046	-0.029	0.0	-0.1	82.1	82.1	0.01
Line968	0.045	0.028	-0.045	-0.028	0.0	0.0	83.3	83.3	0.01
Line970	0.482	0.299	-0.482	-0.299	0.8	0.5	83.3	83.2	0.15
Cable101	-0.482	-0.299	0.482	0.299	0.0	0.0	83.2	83.2	0.00
Line972	0.230	0.143	-0.230	-0.143	0.1	0.0	83.2	83.1	0.03
Line975	0.155	0.095	-0.154	-0.096	0.6	-0.4	90.7	90.4	0.34
Line977	0.010	0.006	-0.010	-0.006	0.0	-0.1	90.4	90.4	0.00
Line978	-1.081	-0.665	1.086	0.667	4.9	1.9	90.8	91.2	0.38
Line980	0.964	0.593	-0.963	-0.592	1.7	0.7	90.8	90.7	0.15
Line982	-0.958	-0.589	0.963	0.592	4.5	3.6	90.2	90.7	0.47
Line984	0.835	0.513	-0.834	-0.512	1.2	1.0	90.2	90.1	0.15
Line986	0.027	0.017	-0.027	-0.017	0.0	0.0	90.1	90.1	0.00

Branch ID	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
Line988	0.807	0.495	-0.800	-0.492	7.3	2.7	90.1	89.3	0.74
Line990	0.648	0.398	-0.643	-0.396	5.5	1.9	89.3	88.6	0.69
Line992	0.040	0.025	-0.040	-0.025	0.0	-0.2	88.6	88.6	0.02
Line994	0.603	0.372	-0.602	-0.371	0.9	0.4	88.6	88.5	0.12
Line996	0.545	0.336	-0.542	-0.335	3.4	1.3	88.5	88.0	0.52
Line998	0.347	0.214	-0.345	-0.214	2.3	0.6	88.0	87.5	0.54
Line1000	0.194	0.120	-0.194	-0.120	0.0	0.0	88.0	88.0	0.02
Line1002	0.064	0.040	-0.064	-0.040	0.0	0.0	88.0	88.0	0.01
					1026.5	2790.0			

Alert Summary Report

	% Alert Settings	
	Critical	**Marginal**
Loading		
Bus	100.0	95.0
Cable	100.0	95.0
Reactor	100.0	95.0
Line	100.0	95.0
Transformer	100.0	85.0
Panel	100.0	95.0
Protective Device	100.0	95.0
Generator	100.0	95.0
Inverter/Charger	100.0	95.0
Bus Voltage		
OverVoltage	110.0	105.0
UnderVoltage	90.0	95.0
Generator Excitation		
OverExcited (Q Max.)	100.0	95.0
UnderExcited (Q Min.)	100.0	

Critical Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus1029	Bus	Under Voltage	11.000	kV	9.859	89.6	3-Phase
Bus1030	Bus	Under Voltage	11.000	kV	9.86	89.6	3-Phase
Bus1032	Bus	Under Voltage	11.000	kV	9.83	89.4	3-Phase
Bus1033	Bus	Under Voltage	11.000	kV	9.83	89.4	3-Phase
Bus1034	Bus	Under Voltage	11.000	kV	9.83	89.4	3-Phase
Bus1036	Bus	Under Voltage	11.000	kV	9.74	88.6	3-Phase
Bus1038	Bus	Under Voltage	11.000	kV	9.63	87.6	3-Phase
Bus1040	Bus	Under Voltage	11.000	kV	9.56	86.9	3-Phase
Bus1041	Bus	Under Voltage	11.000	kV	9.56	86.9	3-Phase
Bus1043	Bus	Under Voltage	11.000	kV	9.47	86.1	3-Phase
Bus1045	Bus	Under Voltage	11.000	kV	9.47	86.1	3-Phase
Bus1047	Bus	Under Voltage	11.000	kV	9.47	86.1	3-Phase
Bus1049	Bus	Under Voltage	11.000	kV	9.32	84.7	3-Phase
Bus1051	Bus	Under Voltage	11.000	kV	9.25	84.1	3-Phase
Bus1052	Bus	Under Voltage	11.000	kV	9.25	84.1	3-Phase

Critical Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus1054	Bus	Under Voltage	11.000	kV	9.183	83.5	3-Phase
Bus1056	Bus	Under Voltage	11.000	kV	9.15	83.2	3-Phase
Bus1058	Bus	Under Voltage	11.000	kV	9.11	82.8	3-Phase
Bus1059	Bus	Under Voltage	11.000	kV	9.10	82.8	3-Phase
Bus1060	Bus	Under Voltage	11.000	kV	9.11	82.8	3-Phase
Bus1062	Bus	Under Voltage	11.000	kV	9.06	82.4	3-Phase
Bus1064	Bus	Under Voltage	11.000	kV	9.05	82.3	3-Phase
Bus1066	Bus	Under Voltage	11.000	kV	9.05	82.2	3-Phase
Bus1067	Bus	Under Voltage	11.000	kV	9.05	82.2	3-Phase
Bus1068	Bus	Under Voltage	11.000	kV	9.05	82.2	3-Phase
Bus1070	Bus	Under Voltage	11.000	kV	9.03	82.1	3-Phase
Bus1072	Bus	Under Voltage	11.000	kV	9.03	82.1	3-Phase
Bus1073	Bus	Under Voltage	11.000	kV	9.03	82.1	3-Phase
Bus1075	Bus	Under Voltage	11.000	kV	9.16	83.3	3-Phase
Bus1077	Bus	Under Voltage	11.000	kV	9.15	83.2	3-Phase
Bus1078	Bus	Under Voltage	11.000	kV	9.16	83.3	3-Phase
Bus1079	Bus	Under Voltage	11.000	kV	9.15	83.2	3-Phase
Bus1080	Bus	Under Voltage	11.000	kV	9.15	83.1	3-Phase
Bus1086	Bus	Under Voltage	11.000	kV	9.82	89.3	3-Phase
Bus1096	Bus	Under Voltage	11.000	kV	9.83	89.3	3-Phase
Bus1098	Bus	Under Voltage	11.000	kV	9.75	88.6	3-Phase
Bus1099	Bus	Under Voltage	11.000	kV	9.75	88.6	3-Phase
Bus11	Bus	Under Voltage	11.000	kV	9.73	88.5	3-Phase
Bus1101	Bus	Under Voltage	11.000	kV	9.74	88.5	3-Phase
Bus1103	Bus	Under Voltage	11.000	kV	9.68	88.0	3-Phase
Bus1104	Bus	Under Voltage	11.000	kV	9.62	87.5	3-Phase
Bus1106	Bus	Under Voltage	11.000	kV	9.68	88.0	3-Phase
Bus1108	Bus	Under Voltage	11.000	kV	9.68	88.0	3-Phase
Bus113	Bus	Under Voltage	11.000	kV	9.70	88.2	3-Phase
Bus133	Bus	Under Voltage	11.000	kV	9.82	89.3	3-Phase
Bus138	Bus	Under Voltage	11.000	kV	9.82	89.3	3-Phase
Bus141	Bus	Under Voltage	11.000	kV	9.82	89.2	3-Phase
Bus144	Bus	Under Voltage	11.000	kV	9.69	88.1	3-Phase
Bus148	Bus	Under Voltage	11.000	kV	9.72	88.4	3-Phase
Bus15	Bus	Under Voltage	11.000	kV	9.73	88.5	3-Phase
Bus151	Bus	Under Voltage	11.000	kV	9.75	88.6	3-Phase

Critical Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus153	Bus	Under Voltage	11.000	kV	9.695	88.1	3-Phase
Bus157	Bus	Under Voltage	11.000	kV	9.74	88.5	3-Phase
Bus158	Bus	Under Voltage	11.000	kV	9.89	89.9	3-Phase
Bus159	Bus	Under Voltage	11.000	kV	9.89	89.9	3-Phase
Bus160	Bus	Under Voltage	11.000	kV	9.68	88.0	3-Phase
Bus161	Bus	Under Voltage	11.000	kV	9.86	89.6	3-Phase
Bus162	Bus	Under Voltage	11.000	kV	9.86	89.6	3-Phase
Bus163	Bus	Under Voltage	11.000	kV	9.74	88.5	3-Phase
Bus164	Bus	Under Voltage	11.000	kV	9.84	89.4	3-Phase
Bus165	Bus	Under Voltage	11.000	kV	9.84	89.4	3-Phase
Bus166	Bus	Under Voltage	11.000	kV	9.66	87.8	3-Phase
Bus167	Bus	Under Voltage	11.000	kV	9.79	89.0	3-Phase
Bus169	Bus	Under Voltage	11.000	kV	9.74	88.5	3-Phase
Bus170	Bus	Under Voltage	11.000	kV	9.74	88.5	3-Phase
Bus171	Bus	Under Voltage	11.000	kV	9.63	87.5	3-Phase
Bus172	Bus	Under Voltage	11.000	kV	9.72	88.4	3-Phase
Bus173	Bus	Under Voltage	11.000	kV	9.72	88.4	3-Phase
Bus175	Bus	Under Voltage	11.000	kV	9.72	88.4	3-Phase
Bus176	Bus	Under Voltage	11.000	kV	9.75	88.6	3-Phase
Bus177	Bus	Under Voltage	11.000	kV	9.69	88.1	3-Phase
Bus178	Bus	Under Voltage	11.000	kV	9.61	87.4	3-Phase
Bus179	Bus	Under Voltage	11.000	kV	9.60	87.3	3-Phase
Bus180	Bus	Under Voltage	11.000	kV	9.59	87.2	3-Phase
Bus181	Bus	Under Voltage	11.000	kV	9.60	87.3	3-Phase
Bus183	Bus	Under Voltage	11.000	kV	9.60	87.3	3-Phase
Bus184	Bus	Under Voltage	11.000	kV	9.60	87.3	3-Phase
Bus186	Bus	Under Voltage	11.000	kV	9.60	87.3	3-Phase
Bus187	Bus	Under Voltage	11.000	kV	9.60	87.3	3-Phase
Bus189	Bus	Under Voltage	11.000	kV	9.59	87.2	3-Phase
Bus190	Bus	Under Voltage	11.000	kV	9.59	87.2	3-Phase
Bus191	Bus	Under Voltage	11.000	kV	9.58	87.1	3-Phase
Bus193	Bus	Under Voltage	11.000	kV	9.60	87.3	3-Phase
Bus194	Bus	Under Voltage	11.000	kV	9.60	87.3	3-Phase
Bus28	Bus	Under Voltage	11.000	kV	9.73	88.4	3-Phase
Bus335	Bus	Under Voltage	11.000	kV	9.82	89.3	3-Phase
Bus337	Bus	Under Voltage	11.000	kV	9.82	89.3	3-Phase

Critical Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus339	Bus	Under Voltage	11.000	kV	9.819	89.3	3-Phase
Bus341	Bus	Under Voltage	11.000	kV	9.82	89.3	3-Phase
Bus345	Bus	Under Voltage	11.000	kV	9.82	89.3	3-Phase
Bus347	Bus	Under Voltage	11.000	kV	9.82	89.3	3-Phase
Bus349	Bus	Under Voltage	11.000	kV	9.77	88.8	3-Phase
Bus351	Bus	Under Voltage	11.000	kV	9.72	88.4	3-Phase
Bus353	Bus	Under Voltage	11.000	kV	9.70	88.2	3-Phase
Bus355	Bus	Under Voltage	11.000	kV	9.63	87.6	3-Phase
Bus357	Bus	Under Voltage	11.000	kV	9.63	87.6	3-Phase
Bus358	Bus	Under Voltage	11.000	kV	9.63	87.5	3-Phase
Bus361	Bus	Under Voltage	11.000	kV	9.66	87.8	3-Phase
Bus362	Bus	Under Voltage	11.000	kV	9.66	87.8	3-Phase
Bus364	Bus	Under Voltage	11.000	kV	9.65	87.7	3-Phase
Bus366	Bus	Under Voltage	11.000	kV	9.65	87.7	3-Phase
Bus368	Bus	Under Voltage	11.000	kV	9.65	87.7	3-Phase
Bus370	Bus	Under Voltage	11.000	kV	9.65	87.8	3-Phase
Bus372	Bus	Under Voltage	11.000	kV	9.65	87.7	3-Phase
Bus375	Bus	Under Voltage	11.000	kV	9.74	88.6	3-Phase
Bus377	Bus	Under Voltage	11.000	kV	9.74	88.5	3-Phase
Bus379	Bus	Under Voltage	11.000	kV	9.74	88.5	3-Phase
Bus381	Bus	Under Voltage	11.000	kV	9.73	88.5	3-Phase
Bus383	Bus	Under Voltage	11.000	kV	9.73	88.5	3-Phase
Bus385	Bus	Under Voltage	11.000	kV	9.72	88.3	3-Phase
Bus387	Bus	Under Voltage	11.000	kV	9.71	88.3	3-Phase
Bus389	Bus	Under Voltage	11.000	kV	9.70	88.1	3-Phase
Bus391	Bus	Under Voltage	11.000	kV	9.69	88.1	3-Phase
Bus393	Bus	Under Voltage	11.000	kV	9.69	88.1	3-Phase
Bus397	Bus	Under Voltage	11.000	kV	9.68	88.0	3-Phase
Bus399	Bus	Under Voltage	11.000	kV	9.68	88.0	3-Phase
Bus40	Bus	Under Voltage	11.000	kV	9.72	88.4	3-Phase
Bus401	Bus	Under Voltage	11.000	kV	9.67	87.9	3-Phase
Bus403	Bus	Under Voltage	11.000	kV	9.67	87.9	3-Phase
Bus405	Bus	Under Voltage	11.000	kV	9.67	87.9	3-Phase
Bus407	Bus	Under Voltage	11.000	kV	9.67	87.9	3-Phase
Bus409	Bus	Under Voltage	11.000	kV	9.67	87.9	3-Phase
Bus411	Bus	Under Voltage	11.000	kV	9.67	87.9	3-Phase

Critical Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus413	Bus	Under Voltage	11.000	kV	9.667	87.9	3-Phase
Bus415	Bus	Under Voltage	11.000	kV	9.70	88.2	3-Phase
Bus417	Bus	Under Voltage	11.000	kV	9.61	87.3	3-Phase
Bus419	Bus	Under Voltage	11.000	kV	9.56	86.9	3-Phase
Bus421	Bus	Under Voltage	11.000	kV	9.56	86.9	3-Phase
Bus423	Bus	Under Voltage	11.000	kV	9.56	86.9	3-Phase
Bus425	Bus	Under Voltage	11.000	kV	9.52	86.6	3-Phase
Bus427	Bus	Under Voltage	11.000	kV	9.52	86.6	3-Phase
Bus55	Bus	Under Voltage	11.000	kV	9.71	88.3	3-Phase
Bus66	Bus	Under Voltage	11.000	kV	9.71	88.3	3-Phase
Bus75	Bus	Under Voltage	11.000	kV	9.70	88.2	3-Phase
Bus85	Bus	Under Voltage	11.000	kV	9.70	88.2	3-Phase
Bus956	Bus	Under Voltage	11.000	kV	9.82	89.3	3-Phase
Bus97	Bus	Under Voltage	11.000	kV	9.70	88.2	3-Phase
Bus975	Bus	Under Voltage	11.000	kV	9.78	88.9	3-Phase
Bus977	Bus	Under Voltage	11.000	kV	9.77	88.9	3-Phase
Bus979	Bus	Under Voltage	11.000	kV	9.72	88.3	3-Phase
Bus980	Bus	Under Voltage	11.000	kV	9.70	88.2	3-Phase
Bus981	Bus	Under Voltage	11.000	kV	9.70	88.2	3-Phase
Bus983	Bus	Under Voltage	11.000	kV	9.64	87.7	3-Phase
Bus985	Bus	Under Voltage	11.000	kV	9.63	87.6	3-Phase
Bus987	Bus	Under Voltage	11.000	kV	9.62	87.5	3-Phase
Bus989	Bus	Under Voltage	11.000	kV	9.62	87.4	3-Phase
Bus991	Bus	Under Voltage	11.000	kV	9.62	87.4	3-Phase
Bus993	Bus	Under Voltage	11.000	kV	9.62	87.4	3-Phase
Bus995	Bus	Under Voltage	11.000	kV	9.62	87.4	3-Phase
Bus996	Bus	Under Voltage	11.000	kV	9.62	87.4	3-Phase
Bus997	Bus	Under Voltage	11.000	kV	9.62	87.4	3-Phase
Bus998	Bus	Under Voltage	11.000	kV	9.62	87.4	3-Phase
Cable95	Cable	Overload	190.577	Amp	243.39	127.7	3-Phase
Tshongdu T1	Transformer	Overload	5.000	MVA	5.11	102.2	3-Phase

Marginal Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus10	Bus	Under Voltage	11.000	kV	10.145	92.2	3-Phase
Bus100	Bus	Under Voltage	11.000	kV	9.96	90.5	3-Phase

Marginal Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus1000	Bus	Under Voltage	11.000	kV	9.979	90.7	3-Phase
Bus1002	Bus	Under Voltage	11.000	kV	9.96	90.6	3-Phase
Bus1003	Bus	Under Voltage	11.000	kV	9.94	90.3	3-Phase
Bus1004	Bus	Under Voltage	11.000	kV	9.94	90.3	3-Phase
Bus1006	Bus	Under Voltage	11.000	kV	9.96	90.6	3-Phase
Bus1008	Bus	Under Voltage	11.000	kV	9.96	90.5	3-Phase
Bus1010	Bus	Under Voltage	11.000	kV	9.95	90.4	3-Phase
Bus1011	Bus	Under Voltage	11.000	kV	9.95	90.4	3-Phase
Bus1013	Bus	Under Voltage	11.000	kV	9.95	90.4	3-Phase
Bus1014	Bus	Under Voltage	11.000	kV	9.95	90.4	3-Phase
Bus1016	Bus	Under Voltage	11.000	kV	9.98	90.7	3-Phase
Bus1018	Bus	Under Voltage	11.000	kV	9.98	90.7	3-Phase
Bus102	Bus	Under Voltage	11.000	kV	9.95	90.5	3-Phase
Bus1020	Bus	Under Voltage	11.000	kV	9.97	90.7	3-Phase
Bus1022	Bus	Under Voltage	11.000	kV	9.97	90.6	3-Phase
Bus1024	Bus	Under Voltage	11.000	kV	9.97	90.6	3-Phase
Bus1025	Bus	Under Voltage	11.000	kV	9.97	90.6	3-Phase
Bus1026	Bus	Under Voltage	11.000	kV	9.97	90.6	3-Phase
Bus1027	Bus	Under Voltage	11.000	kV	9.91	90.1	3-Phase
Bus104	Bus	Under Voltage	11.000	kV	9.96	90.5	3-Phase
Bus108	Bus	Under Voltage	11.000	kV	9.96	90.5	3-Phase
Bus1081	Bus	Under Voltage	11.000	kV	9.98	90.7	3-Phase
Bus1083	Bus	Under Voltage	11.000	kV	9.94	90.4	3-Phase
Bus1084	Bus	Under Voltage	11.000	kV	9.94	90.4	3-Phase
Bus1085	Bus	Under Voltage	11.000	kV	9.99	90.8	3-Phase
Bus1087	Bus	Under Voltage	11.000	kV	9.99	90.8	3-Phase
Bus1088	Bus	Under Voltage	11.000	kV	10.03	91.2	3-Phase
Bus1090	Bus	Under Voltage	11.000	kV	9.93	90.2	3-Phase
Bus1091	Bus	Under Voltage	11.000	kV	9.98	90.7	3-Phase
Bus1093	Bus	Under Voltage	11.000	kV	9.91	90.1	3-Phase
Bus1094	Bus	Under Voltage	11.000	kV	9.91	90.1	3-Phase
Bus110	Bus	Under Voltage	11.000	kV	9.96	90.5	3-Phase
Bus116	Bus	Under Voltage	11.000	kV	9.96	90.5	3-Phase
Bus119	Bus	Under Voltage	11.000	kV	9.96	90.5	3-Phase
Bus123	Bus	Under Voltage	11.000	kV	9.96	90.5	3-Phase
Bus125	Bus	Under Voltage	11.000	kV	9.95	90.5	3-Phase

Marginal Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus127	Bus	Under Voltage	11.000	kV	10.149	92.3	3-Phase
Bus13	Bus	Under Voltage	11.000	kV	10.05	91.4	3-Phase
Bus130	Bus	Under Voltage	11.000	kV	10.15	92.3	3-Phase
Bus131	Bus	Under Voltage	11.000	kV	10.15	92.3	3-Phase
Bus147	Bus	Under Voltage	11.000	kV	10.13	92.1	3-Phase
Bus149	Bus	Under Voltage	11.000	kV	10.12	92.0	3-Phase
Bus150	Bus	Under Voltage	11.000	kV	10.12	92.0	3-Phase
Bus152	Bus	Under Voltage	11.000	kV	10.11	91.9	3-Phase
Bus154	Bus	Under Voltage	11.000	kV	10.08	91.6	3-Phase
Bus155	Bus	Under Voltage	11.000	kV	10.07	91.6	3-Phase
Bus156	Bus	Under Voltage	11.000	kV	10.14	92.2	3-Phase
Bus16	Bus	Under Voltage	11.000	kV	10.05	91.4	3-Phase
Bus17	Bus	Under Voltage	11.000	kV	10.05	91.3	3-Phase
Bus195	Bus	Under Voltage	11.000	kV	10.14	92.2	3-Phase
Bus196	Bus	Under Voltage	11.000	kV	10.14	92.2	3-Phase
Bus197	Bus	Under Voltage	11.000	kV	10.14	92.2	3-Phase
Bus198	Bus	Under Voltage	11.000	kV	10.14	92.2	3-Phase
Bus200	Bus	Under Voltage	11.000	kV	10.11	91.9	3-Phase
Bus202	Bus	Under Voltage	11.000	kV	10.09	91.8	3-Phase
Bus204	Bus	Under Voltage	11.000	kV	10.09	91.7	3-Phase
Bus205	Bus	Under Voltage	11.000	kV	10.09	91.7	3-Phase
Bus206	Bus	Under Voltage	11.000	kV	10.14	92.2	3-Phase
Bus21	Bus	Under Voltage	11.000	kV	10.05	91.3	3-Phase
Bus26	Bus	Under Voltage	11.000	kV	10.04	91.3	3-Phase
Bus33	Bus	Under Voltage	11.000	kV	10.01	91.0	3-Phase
Bus373	Bus	Under Voltage	11.000	kV	9.98	90.8	3-Phase
Bus39	Bus	Under Voltage	11.000	kV	10.01	91.0	3-Phase
Bus43	Bus	Under Voltage	11.000	kV	10.01	91.0	3-Phase
Bus463	Bus	Under Voltage	11.000	kV	9.98	90.8	3-Phase
Bus47	Bus	Under Voltage	11.000	kV	10.01	91.0	3-Phase
Bus5	Bus	Under Voltage	11.000	kV	10.11	91.9	3-Phase
Bus50	Bus	Under Voltage	11.000	kV	10.01	91.0	3-Phase
Bus52	Bus	Under Voltage	11.000	kV	10.01	91.0	3-Phase
Bus57	Bus	Under Voltage	11.000	kV	9.99	90.8	3-Phase
Bus59	Bus	Under Voltage	11.000	kV	9.99	90.8	3-Phase
Bus64	Bus	Under Voltage	11.000	kV	9.98	90.7	3-Phase

Marginal Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus68	Bus	Under Voltage	11.000	kV	9.974	90.7	3-Phase
Bus7	Bus	Under Voltage	11.000	kV	10.08	91.6	3-Phase
Bus72	Bus	Under Voltage	11.000	kV	9.97	90.6	3-Phase
Bus76	Bus	Under Voltage	11.000	kV	9.97	90.6	3-Phase
Bus77	Bus	Under Voltage	11.000	kV	9.97	90.6	3-Phase
Bus82	Bus	Under Voltage	11.000	kV	9.97	90.6	3-Phase
Bus9	Bus	Under Voltage	11.000	kV	10.14	92.2	3-Phase
Bus91	Bus	Under Voltage	11.000	kV	9.97	90.6	3-Phase
Bus933	Bus	Under Voltage	11.000	kV	9.99	90.8	3-Phase
Bus95	Bus	Under Voltage	11.000	kV	9.96	90.5	3-Phase
Bus953	Bus	Under Voltage	33.000	kV	31.11	94.3	3-Phase
Bus958	Bus	Under Voltage	11.000	kV	9.98	90.8	3-Phase
Bus960	Bus	Under Voltage	33.000	kV	30.97	93.8	3-Phase
Bus961	Bus	Under Voltage	33.000	kV	30.97	93.8	3-Phase
Bus963	Bus	Under Voltage	11.000	kV	10.03	91.2	3-Phase
Bus964	Bus	Under Voltage	11.000	kV	10.15	92.3	3-Phase
Bus973	Bus	Under Voltage	11.000	kV	9.95	90.4	3-Phase
Bus999	Bus	Under Voltage	11.000	kV	9.98	90.7	3-Phase
Shaba Transformer	Transformer	Overload	5.000	MVA	4.50	90.0	3-Phase

SUMMARY OF TOTAL GENERATION , LOADING & DEMAND

	MW	Mvar	MVA	% PF
Source (Swing Buses):	24.764	17.501	30.324	81.66 Lagging
Source (Non-Swing Buses):	0.000	0.000	0.000	
Total Demand:	24.764	17.501	30.324	81.66 Lagging
Total Motor Load:	8.365	5.184	9.841	85.00 Lagging
Total Static Load:	15.373	9.527	18.086	85.00 Lagging
Total Constant I Load:	0.000	0.000	0.000	
Total Generic Load:	0.000	0.000	0.000	
Apparent Losses:	1.026	2.790		
System Mismatch:	0.000	0.000		

Number of Iterations: 4

Annexure 5: Feeder Wise Reliability Indices

Sl.No.	Year	Month	Reliability Indices	33kV Feeder - I(Towards Drugyel)	33kV feeder No. III (Towards Shaba)	33kV feeder No. IV (Towards Jangsa)	33kV Feeder - I (Shemagang kha feeder)	33kV Feeder (Paro feeder)
1	2017	January	SAIFI	0.46	2.27			
			SAIDI	0.50	4.10			
2		February	SAIFI	0.46	1.30			
			SAIDI	0.40	0.78			
3		March	SAIFI	1.13	5.40		1.04	0.76
			SAIDI	3.80	9.80		0.79	2.70
4		April	SAIFI	1.13	1.29		0.45	
			SAIDI	3.85	2.40		0.19	
5		May	SAIFI	0.23	0.64		0.45	
			SAIDI	0.07	0.42		0.19	
6		June	SAIFI	0.44	0.63			
			SAIDI	3.41	0.50			
7		July	SAIFI	0.22	1.26		0.19	
			SAIDI	0.18	2.90		0.05	
8		August	SAIFI	0.44	2.83		0.38	1.11
			SAIDI	0.88	2.10		0.56	0.50
9		September	SAIFI	0.22			0.06	0.37
			SAIDI	0.23			0.01	0.44
10		October	SAIFI		1.24		0.19	
			SAIDI		3.54		0.05	
11		November	SAIFI		0.62		0.25	
			SAIDI		1.45		0.07	
12		December	SAIFI		0.61			
			SAIDI		0.34			
	Total		**SAIFI**	**2.68**	**9.12**		**1.97**	**1.48**
			SAIDI	**8.62**	**13.65**		**1.12**	**0.94**
1	2018	January	SAIFI	0.12	0.10	0.03		
			SAIDI	0.30	0.05	0.67		
2		February	SAIFI	0.46	1.30			
			SAIDI	0.40	0.78			
3		March	SAIFI	1.13	5.40		1.04	0.76
			SAIDI	3.86	9.80		0.79	2.78
4		April	SAIFI	1.13	1.29		0.45	
			SAIDI	3.80	2.41		0.19	
5		May	SAIFI	0.23	0.64		0.45	
			SAIDI	0.10	0.42		0.19	
6		June	SAIFI	0.44	0.63		0.06	
			SAIDI	3.41	0.50		0.02	
7		July	SAIFI	0.22	1.26		0.19	
			SAIDI	0.18	2.90		0.05	
8		August	SAIFI	0.44	2.83		0.38	1.11
			SAIDI	0.88	2.10		0.56	0.50
9		September	SAIFI	0.22			0.06	0.37
			SAIDI	0.23			0.01	0.44
10		October	SAIFI		1.24		0.19	
			SAIDI		3.59		0.05	
11		November	SAIFI		0.62		0.25	
			SAIDI		1.45		0.07	
12		December	SAIFI		0.61			
			SAIDI		0.34			
	Total		**SAIFI**	**4.39**	**15.92**	**0.03**	**3.07**	**2.24**
			SAIDI	**13.16**	**24.34**	**0.67**	**1.92**	**3.72**
1		January	SAIFI	0.41	1.16			
			SAIDI	0.15	2.41			
2		February	SAIFI	0.41	0.58			
			SAIDI	0.20	0.76			
3		March	SAIFI	0.20	1.74			
			SAIDI	0.05	1.79			
4		April	SAIFI	0.58	0.28			
			SAIDI	6.02	0.02			

Sl.No.	Year	Month	Reliability Indices	33kV Feeder - I(Towards Drugyel)	33kV feeder No. III (Towards Shaba)	33kV feeder No. IV (Towards Jangsa)	33kV Feeder - I (Shemagang kha feeder)	33kV Feeder (Paro feeder)
5	2019	May	SAIFI	0.19	1.36			
			SAIDI	0.05	1.62			
6		June	SAIFI	0.41	1.16			
			SAIDI	0.15	2.41			
7		July	SAIFI	0.19	0.28			
			SAIDI	0.05	0.05			
8		August	SAIFI	0.07	0.81			
			SAIDI	0.02	0.76			
9		September	SAIFI	0.39	0.28			
			SAIDI	0.32	0.73			
10		October	SAIFI		0.28			
			SAIDI		0.91			
11		November	SAIFI					
			SAIDI					
12		December	SAIFI					
			SAIDI					
	Total		**SAIFI**	**2.85**	**7.93**	**-**	**-**	**-**
			SAIDI	**7.01**	**11.46**	**-**	**-**	**-**
	Overall total		**SAIFI**	**3.31**	**10.99**	**0.02**	**1.68**	**1.24**
			SAIDI	**9.60**	**16.48**	**0.34**	**1.01**	**1.55**

Annexure 6: Material Cost for Upgrading single phase (11 kV and 33 kV) Lines to three-phase

Sl. No	Name of ESDs	Total Cost in Nu. For upgradation of Line to 3Φ from 1Φ		Total cost in Nu.
		11 kV Line in Km	33 kV Line in Km	
		Cost in Nu.	Cost in Nu.	
1	Bumthang	604,083.80	626,364.17	1,230,447.97
2	Chukhha	1,372,746.06	6,450,371.80	7,823,117.86
3	Dagana	–	2,495,645.61	2,495,645.61
4	Haa	–	341,755.04	341,755.04
5	Lhuntse	1,648,680.77	6,292,698.01	7,941,378.78
6	Mongar	–	–	–
7	Paro	1,576,599.08	1,663,407.47	3,240,006.55
8	Pemagatshel	–	2,467,625.51	2,467,625.51
9	Punakha	612,259.13	8,183,731.48	8,795,990.60
10	S/Jongkhar	–	7,593,301.40	7,593,301.40
11	Samtse	2,031,083.74	536,799.03	2,567,882.76
12	Sarpang	756,490.07	1,112,902.61	1,869,392.68
13	Trashi Gang	251,649.96	626,304.45	877,954.41
14	Trashiyangtse		2,207,281.49	2,207,281.49
15	Thimphu	5,228,316.74	-	5,228,316.74
16	Trongsa	–	651,860.25	651,860.25
17	Tsirang	–	1,693,286.88	1,693,286.88
18	Wangdue	98,146.90	3,133,078.14	3,231,225.04
19	Zhemgang	–	5,303,863.16	5,303,863.16
	TOTAL	**14,180,056.24**	**51,380,276.50**	**65,560,332.75**

The cost of extending one phase in case of ACSR conductor and AAAC covered conductor were considered and incase of HV ABC, the cost of constructing three core cable has been considered in estimation. Above estimation indicates the total material cost involved in upgrading the existing single-phase line to three phase under each ESD.

The total cost including material cost (Nu. 65 million), transportation cost (Nu. 3.47 million) and labor cost (Nu. 28 million) will amount to Nu. 97 million.

11 kV and 33 kV Single-phase Line Length in km under each ESD

Sl. No	Name of ESDs	11kV 1Φ Line (km)	33kV 1Φ Line (km)	Total 1Φ Line (km)
1	Bumthang	6.96276	5.6246	12.58736
2	Chukhha	21.569	78.274	99.843

Sl. No	Name of ESDs	11kV 1Φ Line (km)	33kV 1Φ Line (km)	Total 1Φ Line (km)
3	Dagana	0	30.527	30.527
4	Haa	0	4.391	4.391
5	Lhuntse	18.7075	80.851	99.5585
6	Mongar	0	0	0
7	Paro	24.772	14.937	39.709
8	Pemagatshel	0	31.705	31.705
9	Punakha	9.62	58.4	68.02
10	S/Jongkhar	0	93.672	93.672
11	Samtse	31.913	6.897	38.81
12	Sarpang	11.8862	14.299	26.1852
13	Trashigang	3.954	8.047	12.001
14	Trashiyangtse	0	28.36	28.36
15	Thimphu	5.93	0	5.93
16	Trongsa	0	5.383	5.383
17	Tsirang	0	21.756	21.756
18	Wangdue	1.01	29.7	30.71
19	Zhemgang	0	66.785	66.785
TOTAL		**136.32446**	**579.6086**	**715.93306**

Annexure 7: Distribution Transformer Loading

Sl.No.	Name of Feeder	Capacity (kVA)	Peak Load (kVA)	2019% Loading	Peak load 2025(kVA)	% 2025 Loading	Peak load 2030(kVA)	% 2030 Loading	Remarks
	33kV Shaba Feeder (Pangbesa)								
1	Issuna 1(near main road)	63	61	97%	67	106%	72	114%	
2	Tshongkha village	100	76.5	77%	102	102%	107.1	107%	
3	Lagay	63	45.74	73%	73.7	117%	97	154%	
	11kV RBA Feeder								
1	RBA 2	500	393.84	79%	510.00	102%	607.00	121%	
2	Upper Jangtoena	63	100	159%	106.00	168%	111.00	176%	
3	Chang Dungka I	100	58	58%	106.00	106%	146	146%	
	11kV Shabara Feeder								
1	Shaba high school	125	194.88	156%	194.88	156%	194.88	156%	
	11kV Hephu Feeder								
1	Gup tshering orchard	63	77	122%	77	122%	77	122%	
	11kV Drujidingkha Feeder								
1	Shab Shelgo	63	108.24	172%	168.00	267%	218.00	346%	
2	Drugidingkha I	100	65.04	65%	96	96%	122	122%	
3	Dzongdrakha I	63	94	149%	94	149%	94	149%	
4	Woochu	160	234.6	147%	393	246%	525	328%	
5	BAFRA	125	62	50%	110	88%	150	120%	
6	Damtsibu/Tashi Namgay Resort	500	320	64%	506	101%	661	132%	
	11kV Drugyel Feeder								
1	Nyemjo Regitsawa	63	48	76%	66	105%	81	129%	
2	Upper Lamgong	125	60.207	48%	80	64%	130	104%	
3	Chunju	63	40.28	64%	62.6	99%	81.2	129%	
	11kV Balakha Feeder								
1	Yamji	63	50	79%	86	137%	116	184%	Rural
	11kV Taktsang Feeder								
1	Taktshang	100	39.46	63%	57.1	91%	71.8	114%	Rural
2	Tshenshi	63	95.58	96%	115	115%	131	131%	Rural
	11kV Kichu Feeder								
1	Nichiphu	125	145.92	117%	258	206%	351	281%	Semi urban
2	Kitchu resort	160	164	103%	164	103%	164	103%	Private
3	Gonju	250	190.3	76%	351	140%	484	194%	Semi urban
4	Dagophu	250	109.6	44%	274	110%	411	164%	Semi urban
	11kV Dotey Feeder								
1	Dop Duzhi	63	51.78	82%	63.3	100%	72.9	116%	Rural
2	Dotey school	63	45	71%	63	100%	75	119%	School
3	Kinga school	63	77.68	123%	118	187%	152	241%	College
	11kV Tshendona Feeder								
1	Kitchu	250	180	72%	225	90%	250	100%	Semi urban
2	Lower Ngoba	160	87.84	55%	150	94%	202	126%	Semi urban
3	Naktsel resort	500	289	58%	500	100%	595	119%	Semi urban
	11kV Ta-Dzong Feeder								
1	Shari Bara	250	212	85%	250	100%	300	120%	Semi urban
	11kV Town Feeder								
1	Old Pema Tshongkhang II	500	456	91%	792	158%	1072	214%	Urban
2	Dago old B mobile I	500	300	60%	400	80%	500	100%	Urban
3	Sunday Market I	1000	700	70%	750	75%	1000	100%	Urban
4	Wangchuk wood tech	500	316.9	63%	498	100%	648	130%	Furniture house
5	upper Gaptey	250	229	92%	250	100%	350	140%	Semi urban
6	Drangzhi Goenpa	63	52.88	84%	72.2	115%	88.3	140%	Semi urban
	11kV Airport Feeder								
1	Chumina	100	80.98	81%	138	138%	185	185%	Semi urban
2	Upper Khangkhu	315	218	69%	284	90%	339	108%	Semi urban
3	Druk Air hanger	500	247.12	49%	508	102%	725	145%	
4	Druk Air I	1600	1093	68%	1597	100%	2017	126%	
5	Nemi Zampa	250	225	90%	300	120%	400	160%	Urban
6	Redfort Uma	160	71	44%	143	89%	203	127%	Private

Annexure-8: Material Cost of three phase (3Φ) Transformers

Sl. No	Name of ESDs	Cost for replacement of single-phase transformers and distribution boards with three-phase		Total cost in Nu.
		11 kV transformers	33 kV transformers	
		Cost in Nu.	Cost in Nu.	
1	Bumthang	421,565.09	132,535.04	554,100.14
2	Chukhha	956,241.73	9,144,917.99	10,101,159.72
3	Dagana	–	6,361,682.08	6,361,682.08
4	Haa	–	3,048,306.00	3,048,306.00
5	Lhuntse	731,506.19	8,747,312.86	9,478,819.05
6	Mongar	182,876.55	4,108,586.34	4,291,462.89
7	Paro	836,897.46	1,060,280.35	1,897,177.81
8	Pemagatshel	91,438.27	6,759,287.21	6,850,725.48
9	Punakha	274,314.82	4,771,261.56	5,045,576.38
10	S/Jongkhar	–	15,506,600.07	15,506,600.07
11	Samtse	6,674,993.95	4,241,121.39	10,916,115.34
12	Sarpang	2,053,501.01	3,445,911.13	5,499,412.14
13	Trashi Gang	906,662.46	4,903,796.60	5,810,459.06
14	Trashiyangtse	–	4,638,726.52	4,638,726.52
15	Thimphu	723,785.91	–	723,785.91
16	Trongsa	91,438.27	3,445,911.13	3,537,349.40
17	Tsirang	–	5,168,866.69	5,168,866.69
18	Wangdue	182,876.55	1,457,885.48	1,640,762.02
19	Zhemgang	105,391.27	11,928,153.90	12,033,545.17
	TOTAL	**14,233,489.55**	**98,871,142.33**	**113,104,631.87**

Here the existing single-phase transformers and distribution boards were replaced by three phase system, therefore the estimation includes the cost of three phase transformers and distribution boards. In line with Distribution Design and Construction Standard (DDCS) 2015, the transformer capacities according to voltage level are standardized as shown below:

33 kV System		11 kV System	
3 Φ	**1Φ**	**3 Φ**	**1Φ**
25 kVA	25 kVA, 16 kVA	25 kVA, 16 kVA	25 kVA,16 kVA, 10 kVA

Therefore, during the estimation, on 33 kV system, the cost of 25 kVA transformers was taken for 10 kVA and 16 kVA transformers and for 11 kV system, the cost of 16 kVA transformers was taken for 10 kVA ratings. The total cost for replacing the 1-phase transformers under whole ESD including transportation cost (Nu. 2.6 million) and labor cost (Nu. 70 million) is Nu. 186 million. Therefore, the total cost under this option will amount to Nu. 283 million.

11 kV & 33 kV Single-phase Transformers used under each ESD

Sl. No	Name of ESDs	TRANSFORMERS (Nos.)					
		11/0.240 kV			33/0.240 kV		
		10 kVA	16kVA	25kVA	10 kVA	16kVA	25kVA
1	Bumthang	–	–	4	–	1	–
2	Chukhha	2	5	3	19	31	19
3	Dagana	–	–	–	4	43	1
4	Haa	–	–	–	8	13	2
5	Lhuntse	3	5	–	3	19	44
6	Mongar		2	–	12	17	2
7	Paro	5	3	1	6	2	–
8	Pemagatshel	–	1	–	4	8	39
9	Punakha	1	2	–	2	5	29
10	S/Jongkhar	–	–	–	18	24	75
11	Samtse	15	58	–	–	32	–
12	Sarpang	10	9	3	9	8	9
13	Trashi Gang	3	–	6	–	–	37
14	Trashiyangtse	–	–	–	16	19	–
15	Thimphu*	–	1	6	–	–	–
16	Trongsa	1	–	–	9	17	–
17	Tsirang	–	–	–	7	32	–
18	Wangdue	1	1	–	–	2	9
19	Zhemgang	–	–	1	27	36	27
	TOTAL	**41**	**87**	**24**	**144**	**309**	**293**