

# Evaluation by Implementation of Distribution System Planning for Energy Loss Reduction

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## Abstract

*In recent years the nature of load has changed drastically and different electrical machinery i.e. mercury lamps, transformers, motors, switchgears are running inherently at low power factor. This means that power supply authorities have to generate much more current that is theoretically required. This high current level in our system needs to be reduced and efforts should be made to make the system more energy handling with minimum cost involved. This includes different techniques such as improving power factor, changing conductor size, substituting cables with conductors etc.*

*The main objective of this research is to develop methodology and guide lines for distribution engineers to show that by reducing the energy losses of distribution system, available capacity of the system may be conserved without putting up additional capacity. A generalized computer program is used to evaluate any given HT/LT system and propose capacitor banks at different points, different conductor sizes in different portions of system. This results in improving the stability as well as energy handling capacity of the system at minimum cost.*

**Key Words:** Distribution System Planning, Energy loss Reduction, Rehabilitation

## 1. Introduction

WAPDA power system is heavily overloaded because the system has been expanded without proper planning and increasing the required level of capital expenditure. During the last 30-years, energy growth rate of 13.3% and consumer growth rate of more than 11% has been experienced which is very high as compared to the other developing countries[1]. Due to this unplanned expansion in the system, the supply conditions were sacrificed to meet the required targets under political pressure.

Due to this ever increasing demand for power all around, the distribution system of WAPDA remains under pressure. This has in turn caused a drift in the distribution system parameters, thus affecting adversely the reliability of power supply and quality of service to the customers. These conditions warrant timely planning of the strategy for rehabilitation of the overloaded and over stretched system to accommodate the rising load demands [1].

The methodology to increase the capacity of the system can be outlined as;

1. Data collection of given power distribution system.
2. Analysis of the power distribution system at different loads, voltage levels, conductor sizes, current levels etc.
3. Designing of power distribution network by simulating on computer using FEEDER ANALYSIS (FDRANA) software applicable in WAPDA for calculation of different parameters of system such as power factor (before and after the addition of kVARs), voltage drops, power losses (before and after improvements in the system), its comparison in cost involved with respect to benefit gained in specific period of time i.e. three years, five years or ten years whichever is required.
4. Calculation of exact rating/quantity of capacitors required to improve the power factor, length of conductor to be replaced with conductor of required size through the aforesaid software.
5. Energy and cost saving through system improvement.

For this purpose 11 kV Railway Colony, Dars Road and Angoori Bagh Feeders emanating from Pakistan Western Railway & Shalimar Grid Stations are selected. H.T Distribution Rehabilitation Techniques i.e. Bifurcation, Re-conductoring and Capacitor Installation are applied on these feeders. FEEDER ANALYSIS (FDRANA) Computer Software is used to calculate energy losses, voltage drop and Benefit to Cost (B/C) Ratio [1].

## 2. Losses In Distribution System

System losses include transmission losses and distribution losses. The distribution losses make major contribution to the system losses and are about 70% of the total losses. Distribution losses being major share of the system losses needs special attention for achieving remarkable reduction in loss figure. The distribution losses contribute the major portion of the system losses. The losses occurring in the distribution system can be divided into two main parts:

1. Technical Losses
2. Administrative/Non-Technical Losses

Technical losses result from the nature and type of load, design of electrical installation/equipment, layout of installation, poor maintenance of the system, under size and lengthy service lines, over-loading and sub-standard electrical equipments. Non-technical losses result from incorrect meter readings, and/or billing periods, human errors, connection running at site but disconnected in record, non affection of meter change orders in time and pilferage of energy. [2-5]

Non-technical losses of the WAPDA distribution system are extremely high. It is estimated that these losses are more than 33% of the total distribution system losses. Although reduction of these losses may not lower the energy demand and requirement on the distribution system, however it will improve the financial base of WAPDA and provide for a non-equitable base for rate structuring.

This research paper is dealing with the improvement in the technical losses, in particular.

## 3. Rehabilitation of Distribution System

Rehabilitation means to restore the abnormal system to its normal working condition through some economically justified improvement

techniques. The main objective of this rehabilitation is;

1. Reduction of power losses.
2. Improvement of voltage conditions.
3. Improvement of power factor.
4. Accommodation of future load growth.
5. Shifting of the load from overloaded grid station to lightly loaded grid station.
6. Improvement of quality of energy supply and reliability.
7. Improvement of system stability and continuity of supply.
8. Improvement in safety.
9. Improvement of customer service.
10. Reduction in cost of operation and maintenance
11. Improvement of equipment life.

A distribution network is selected for rehabilitation on the basis of certain planning criteria such as voltage drop, power loss, equipment loading and Benefit/Cost ratio, etc. For each selected network, a planning proposal for Energy Loss Reduction (ELR) is prepared to achieve the desired benefits.

### A. Rehabilitation of HT Distribution System

The rehabilitation of HT Distribution System involves following techniques; [1, 6, 7]

1. Area planning without addition of new feeder i.e. shifting of load from heavy loaded feeders to the adjoining lightly loaded feeders in the vicinity.
2. Installation of HT shunt capacitors (fixed or switched).
3. Reconductoring i.e. replacement of existing conductor with higher capacity conductor.
4. Bifurcation of feeder i.e. addition of new feeder, to shift some of the loads of existing feeder.
5. Area planning with addition of new feeders.
6. Sometimes, area planning at grid station level is also required to provide relief to the over loaded grid stations. This is done by shifting the load of overloaded grid stations to nearby under-loaded or newly constructed grid stations. Area Planning may or may not involve new feeders.

## **B. Rehabilitation of LT Distribution System**

The rehabilitation of LT Distribution System involves following techniques;

### ***i. Area Planning of LT Distribution network without addition of new feeders***

In this case, heavily loaded feeders are selected and their load is shifted to nearby lightly loaded feeders to balance the load amongst them. In some cases, due to overloading of grid stations, area planning of feeders is exercised for shifting the load from one grid station to another grid station by making links between the grids. This will not only provide relief to the grid station equipment but also accommodate the future expected load growth. Area Planning may or may not involve new feeders.

### ***ii. Installation of LT shunt capacitor***

Installation of capacitors on HT lines results in primary loss reduction in HT lines and improvement in the voltage drop conditions. Losses in distribution transformers, LT lines and service cables are also reduced marginally [8-10].

### ***iii. Reconductoring of LT Line***

Reconductoring is done when percentage loading of the conductor exceeds economic loading or to replace the deteriorated/off size conductor. Studies of different conductor sizes have indicated that in many cases, it is more economical to use conductors of higher cross sectional area. Replacement of existing line conductors by bigger sized conductors will result in reduction of technical losses in direct proportion to the ratio between the resistance of the new and existing conductor [1].

The cost of Reconductoring must be compared with the saving due to reduction in losses, increase in revenue and relief of distribution system capacity.

Evaluation of Reconductoring must also take into account the improvement of power factor, voltage regulation and increase in demand over the life of the conductor.

### ***iv. Bifurcation of 11kV Lines***

In this case, overloaded or lengthy feeders are selected. Only one feeder is selected for bifurcation and a new feeder is essentially involved in this case.

In many urban and rural areas, the existing HT lines/feeders are extremely overloaded and lengthy. Replacement of these lines with new 11kV lines can result in considerable loss reduction. In addition to above the introduction of new HT line/feeders can result in the improvement of quality of supply and reduction in losses.

### ***v. Area Planning of LT Distribution System with addition of new feeders***

This case is almost similar to above mentioned area planning except that in this case one or more new feeders are proposed to share some of the load of the over loaded feeders.

### ***vi. Installation of LT Distribution System Sectionalizer***

In order to isolate the faulty portions of feeders under fault conditions, proper segmentation of LT distribution network should be carried out to minimize the number of customers affected.

### ***vii. Replacement of deteriorated LT cables (500 MCM/240 mm<sup>2</sup>)***

For new feeders, it is suggested to use 500-MCM cable at grid end and to replace the under-sized/deteriorated cable, where required.

### ***viii. Rehabilitation of HT Distribution System***

Selection criteria for HT network to be rehabilitated is that for Reconductoring, Bifurcation & Area Planning Proposals B/C (Benefit to Cost Ratio)  $> = 2.0$

1. For Reconductoring Proposals, B/C  $> = 1.5$
2. For Bifurcation & Area Planning Proposals, B/C  $> = 2.0$

### ***ix. Rehabilitation of LT Distribution System***

For LT network rehabilitation higher priority is given to those areas where distribution transformers are running beyond 80% loading or LT Line is lengthy, service to service connections exist and consequently, the technical parameters (i.e. % Voltage Drop and % Annual Energy Loss) exceed above permissible limits. Such LT proposals that give maximum technical as well as financial benefits should be executed.

The required B/C for LT proposals  $> = 1$

#### **4. Study of Existing LT Distribution System**

The objective of this research is to design an efficient and low cost power distribution system. For this purpose 11kV Railway Colony, Dars Road and Angoori Bagh Feeders emanating from Pakistan Western Railway & Shalimar Grid Stations are selected. HT Distribution Rehabilitation Techniques are applied on these feeders. Techniques of Bifurcation, Reconductoring and Capacitor Installation are employed in HT Proposal. FEEDER ANALYSIS (FDRANA) Computer Software has been used to carry out Energy Losses and Voltage Drop Calculation, Benefit to Cost Ratio [1].

Load flow analysis of 11kV feeders is conducted to determine the feeder voltage profile with loads and conditions likely to be encountered during the normal operation of the system. The result of load flow analysis is utilized to determine the energy losses and voltage drop of the existing distribution system at different nodes. Finally the calculated results are compared with WAPDA's standards. The results are also compared with each other in order to determine the severity with respect to each other.

##### ***i. Analysis of Existing 11kV Railway Colony Feeder***

11kV, 3-Wire Railway Colony Feeder emanates from 132kV Pakistan Western Railway Grid Station. The Grid has two power transformers connected in parallel having a capacity of 20/26MVA each, 132/11kV. This feeder supplies power to mixed loads mostly residential and commercial with some industrial load.

Physical Survey of existing 11kV Railway Colony Feeder is carried out. Single line diagram of existing Railway Colony feeder is prepared and plotted

Energy losses and voltage drop of existing distribution system is calculated keeping in view the WAPDA requirements. The length of feeder is 10.251km with annual energy loss 801850.1kWH and maximum %age voltage drop is 6.8%, which is beyond the specified limit of WAPDA i.e. 5.0% and is not acceptable.

Detail analysis of energy losses and voltage drop of 11kV Railway Colony Feeder are shown [1].

##### ***ii. Analysis of Existing 11kV Dars Road Feeder***

11kV, 3-Wire Dars Road Feeder emanates from 132kV Pakistan Western Railway Grid Station. The Grid has two power transformers connected in parallel having a capacity of 20/26MVA each, 132/11kV. This feeder supplies power to mixed loads mostly residential and commercial with some industrial load.

Physical Survey of existing 11kV Dars Road Feeder is carried out. Single line diagram of existing Dars Road Feeder has been prepared and plotted.

Energy losses and voltage drop of existing distribution system is calculated keeping in view the WAPDA requirements. The length of feeder is 05.726km with annual energy loss 803238.6kWH and maximum %age voltage drop is 6.4%, which is beyond the specified limit of WAPDA i.e. 5.0% and is not acceptable.

Detail analysis of energy losses and voltage drop of 11kV Dars Road are shown [1].

##### ***iii. Analysis of Existing 11-kV Angoori Bagh Feeder***

11-kV, 3-Wire Angoori Bagh Feeder emanates from 132-KV Shalimar (OLD) Grid Station. This feeder supplies power to mixed loads mostly residential and commercial with some industrial load.

Physical Survey of existing 11kV Angoori Bagh Feeder is carried out. Single line diagram of existing Angoori Bagh feeder is prepared and plotted and is shown in Fig.1. (Annexture-1).

Energy losses and voltage drop of existing distribution system has been calculated keeping in view the WAPDA requirement. The length of feeder is 07.147km with annual energy loss 1120453.1kWH and maximum %age voltage drop is 7.9%, which is beyond the specified limit of WAPDA i.e. 5.0% and is not acceptable.

Detail analysis of energy losses and voltage drop of 11kV Angoori Bagh Feeder are shown in Table 1.

**Table 1: Energy Losses & Voltage Drop Calculations of Existing Angoori Bagh Feeder.**

EXISTING		PROPOSED	BENEFIT
Line Losses	296.0 kW	296.0 kW	0.0
Transformation Losses	0.1 kW	0.1 kW	0.0
Total Power Losses	296.1 kW	296.1 kW	0.0
%Power Losses	5%	5%	0%
Annual Energy Loss	1120453.1 kWh	1120453.1 kWh	0.0
%Annual Energy Loss	4%	4%	0%

### 5. Benefit/Cost Analysis for HT Proposal

The B/C ratio is calculated using the relation,

$$B/C = (\text{Benefit in Rs:} - 0.04 \times C.C - 0.0858 \text{ RRF}) / (0.143 \times C.C)$$

Where C.C means Capital Cost or Investment Cost of Complete HT Proposal [6,8,9,11]

#### i. Calculation of Benefits

**RRF:** Replaced Reconductoring Facility, which means any benefit gained due to Reconductoring.

**S1:** Saving (kWh) due to Bifurcation.

If “A” is loss due to no bifurcation (without Bifurcation), then after Bifurcation, losses at two section will be B&C, and saving due to bifurcation is suppose D where **D = A-(B+C)**.

**S2:** Saving (kWh) due to installation of fixed capacitor at off peak load

**S3:** Saving due to switched capacitors installed and saving calculated at peak load. As no switched capacitors are installed in WAPDA, so this saving is zero, so  $S3 = 0$

**S4:** Saving due to installation of fixed capacitors at peak load but also due to reconductoring.

**S5:**  $S1 + S2 + S3 + S4$

S 5 is saving at present without growth but in 5 years at growth rate of 5 %, the saving will be  $S6 = 1.196 S5$  where 1.196 is saving factor in 5 years at growth rate of 5 years.

**S6:**  $1.196 S5$

**S7:**  $3.76 \times S6$  (Saving in Rs:) =  $3.76$  (unit rate) x Energy Saving (kWh) S 6 is saving in 5-years at growth rate of 5 %. S7 is Total Benefits.

**0.04 CC:** 0.04 is O&M charges or Labour Charges or Installation Charges.

**0.0858:** Transportation of Dismantled Material & Charges of Labour (Man Hour)

**0.143:** Benefits not available at present but can be made available in 5-years.

**0.0858 RRF:** Benefit obtained due to Replaced Recovery Facility (i.e. Conductor which is dismantled is returned to filed store etc.)

**C.C:** Total Cost of HT Proposal.

**3.76:** Unit rate at which energy units is purchased [12].

#### ii. Implementation of HT Proposals

To design an efficient low cost power distribution system, again 11 kV Railway Colony, Dars Road, 11kV Lasani Bagh and 11kV Sabzi Mandi feeder are selected for study and research work [1].

The results of existing 11kV Railway Colony, Dars Road and Angoori Bagh Feeders are compared with existing, modified 11kV Railway Colony, Dars Road and Angoori Bagh Feeders and also proposed 11kV Railway Colony, Dars Road and Angoori Bagh Feeders and benefits to cost ratio is calculated after implementation of HT Rehalitation Proposals. [1]

11kV, 3-Wire Lasani Feeder will emanate from 132kV Shalamar Grid Station. The Grid has two power transformers connected in parallel having a capacity of 20/26MVA each, 132/11kV. This feeder supplies power to mixed loads mostly residential and commercial with some industrial load.

Physical Survey of proposed 11kV Lasani Feeder is carried out. Single line diagram of proposed Lasani Feeder is prepared and plotted and is shown in Fig.2. (Annexture-2)

Energy losses and voltage drop of proposed distribution system is calculated keeping in view the WAPDA requirement. The length of proposed feeder is 6.847km with annual energy loss 221948.9kWH and maximum %age voltage drop is 2.3%, which is as per specified limit of WAPDA i.e. 5.0% and is acceptable.

Detail analysis of energy losses and voltage drop of Proposed 11kV Lasani Feeder are shown [1].

11kV, 3-Wire SABZI MANDI Feeder emanate from 132kV Shalamar Grid Station. The Grid has two power transformers connected in parallel having a capacity of 20/26MVA each, 132/11kV. This feeder supplies power to mixed loads mostly residential and commercial with some industrial load.

The existing 11kV Anguri bagh Feeder is bifurcated into proposed 11kV Lasani Feeder and 11kV Sabzi Mandi Feeder, load flow analysis of proposed 11kV Lasani Feeder and 11kV Sabzi Mandi Feeder is conducted to determine the feeder voltage profile with loads and conditions likely to be encountered during normal operation of the system. The result of load flow analysis is utilized to determine the energy losses and voltage drop of the proposed distribution system at different nodes. Finally the calculated results is compared with WAPDA's standards. The results are also compared with each other in order to determine the severity with respect to each other.

Physical Survey of proposed 11kV Sabzi Mandi Feeder is carried out. Single line diagram of proposed 11kV Sabzi Mandi Feeder is prepared and plotted and is shown in Fig.3. (Annexture-3)

Energy losses and voltage drop of proposed distribution system is calculated keeping in view the WAPDA requirement. The length of proposed feeder is 6.963km with annual energy loss 71572.8kWH and maximum %age voltage drop is 1.7%, which is as per specified limit of WAPDA i.e. 5.0% and is acceptable.

Detail analysis of energy losses and voltage drop of Proposed 11kV Sabzi Mandi Feeder are shown in Table 2.

**Table 2: Energy Losses & Voltage Drop Calculations of Sabzi Mandi Feeder.**

EXISTING		PROPOSED	BENEFIT
Line Losses	18.90 kW	18.9 kW	0.0
Transformation Losses	0.1 kW	0.1 kW	0.0
Total Power Losses	19.0 kW	19.0 kW	0.0
% Power Losses	1%	1%	0%
Annual Energy Loss	71572.8 kWH	71572.8 kWH	0.0
% Annual Energy Loss	1%	1%	0%

Summary of 11kV Lasani Feeder (Propose) in given in Table:3

**Table 3: Energy Losses & Voltage Drop calculations of Lasani Feeder.**

EXISTING		PROPOSED	BENEFIT
Line Losses	58.1kW	51.8 kW	6.8 kW
Transformation Losses	0.1 kW	0.1 kW	0.0 kW
Total Power Losses	58.7kW	51.9kW	6.8 kW
% Power Losses	13%	1%	12%
Annual Energy Loss	221948 kWH	196204 kWH	25744.8 kWH
% Annual Energy Loss	13%	1%	12%

## 6. Recommendations

132kV Old Shalamar Grid Station and 132kV Fateh Garh Grid Station are heavily overloaded whereas sufficient capacity is available at 132kV Pakistan Western Railway Grid Station and New Shalamar Grid Station. Similarly, 11kV Angoori Bagh Feeder and Railway Colony Feeder are running overloaded. The prime objective of this analysis is to shift some load of Old Shalamar Grid Station and Fateh Garh Grid Station (Running Overloaded) to New Shalamar Grid Station and Pakistan Western Railway Grid Station and area planning of these feeders namely Angoori Bagh, Railway Colony, and Dars Road has been considered.

The summary of technical parameters of proposed feeders compared with existing feeders is shown in the Table:4.

**Table 4: Summary of Technical Parameter.**

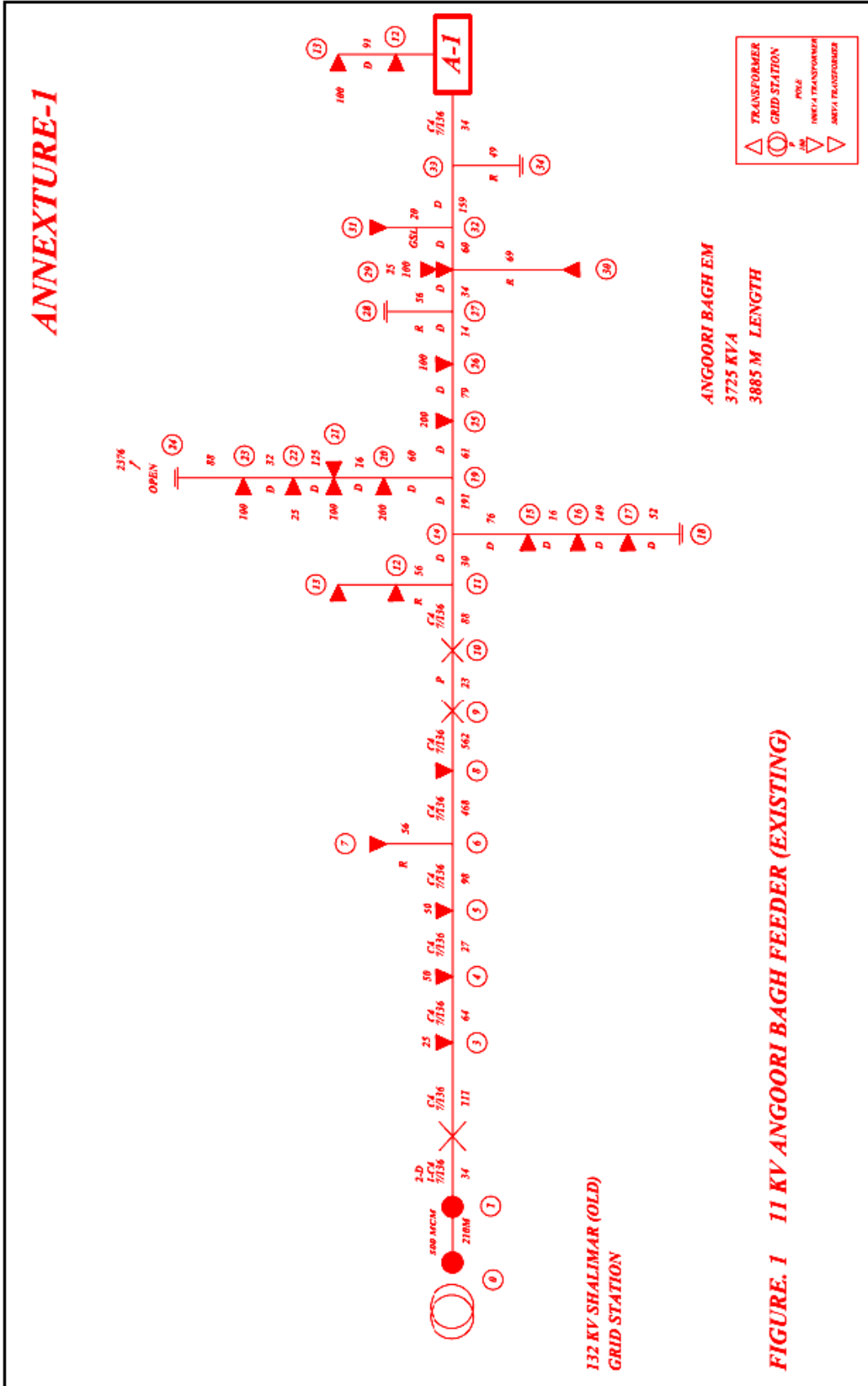
Sr. No.	Technical Parameters	Existing Position of 11-Kv Feeder			Proposed Position of 11-Kv Feeders			
		R/ Colony	D/ Road	A/ Bagh	R/ Colony	D/ Road	IASANI	S/ Mandi
1.	%age Annual energy Loss	20	4.0	4.0	1.0	1.0	1.0	1.0
2.	%age voltage Drop	68	6.4	7.9	3.7	1.7	2.3	1.7
3.	KWH Loss	801,850.1	1308,520.2	1120,453.1	345,113.0	70,207.4	196,204.1	71,572.8

## 7. Conclusions

This analysis will provide detail and comprehensive information on the power factor improvement thereby saving energy and ultimately improving efficiency of electrical system. The analyzed software on this topic will help in coping the problems of power loads, load flow and beneficial in understanding the high penalty charges levied by WAPDA. It will also indicate the benefits in terms of reduced current and losses, which can be achieved by using the computer software. This study will be helpful in calculating the investment involved and also payback of the investment in due course of time. It is also concluded from the above results that after execution of HT proposals any existing power distribution system can be designed as an efficient low cost power distribution system by applying Rehabilitation Techniques on it. It is therefore, recommended that LESCO (WAPDA) may rehabilitate its existing system to achieve fruitful results.

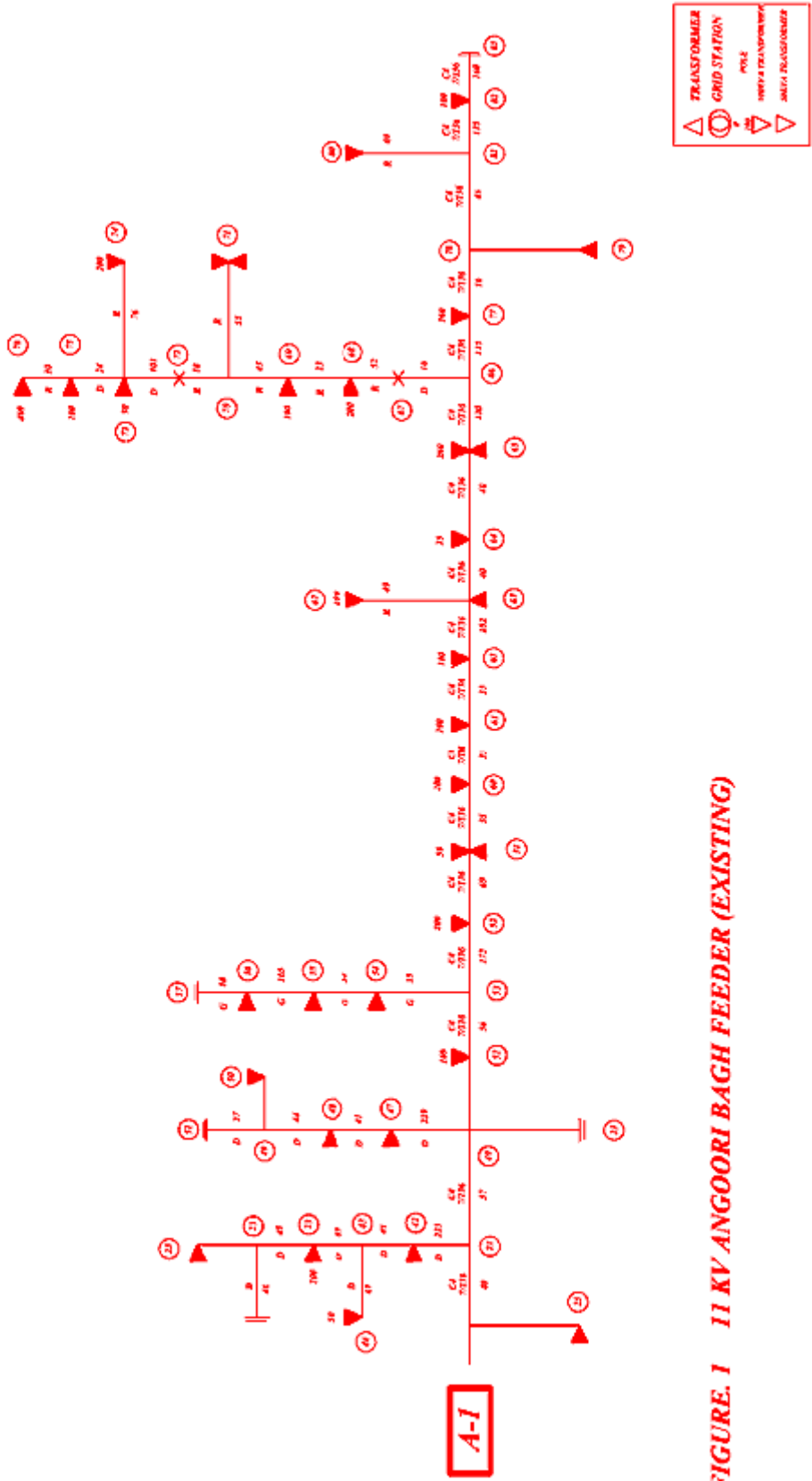
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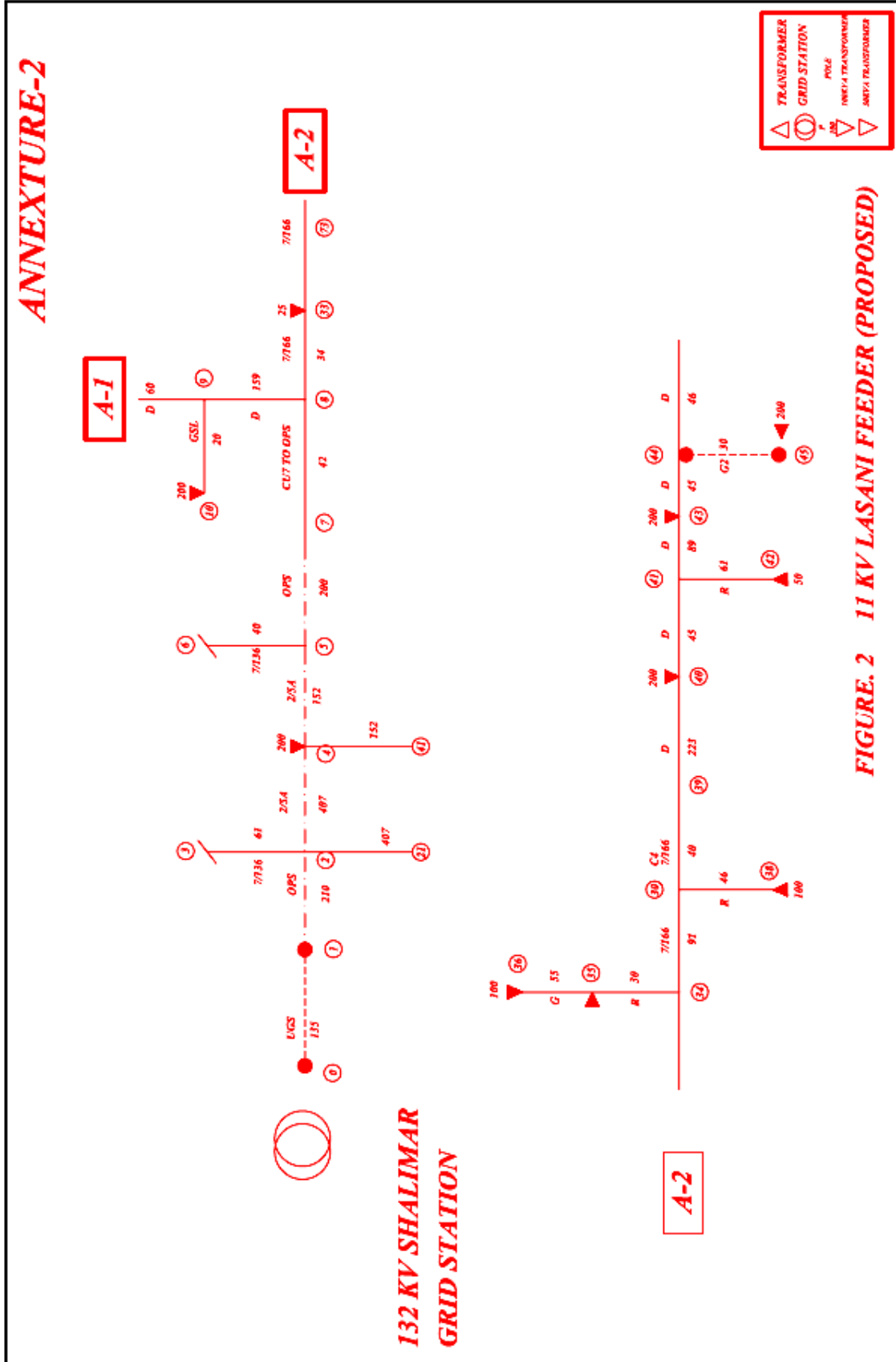




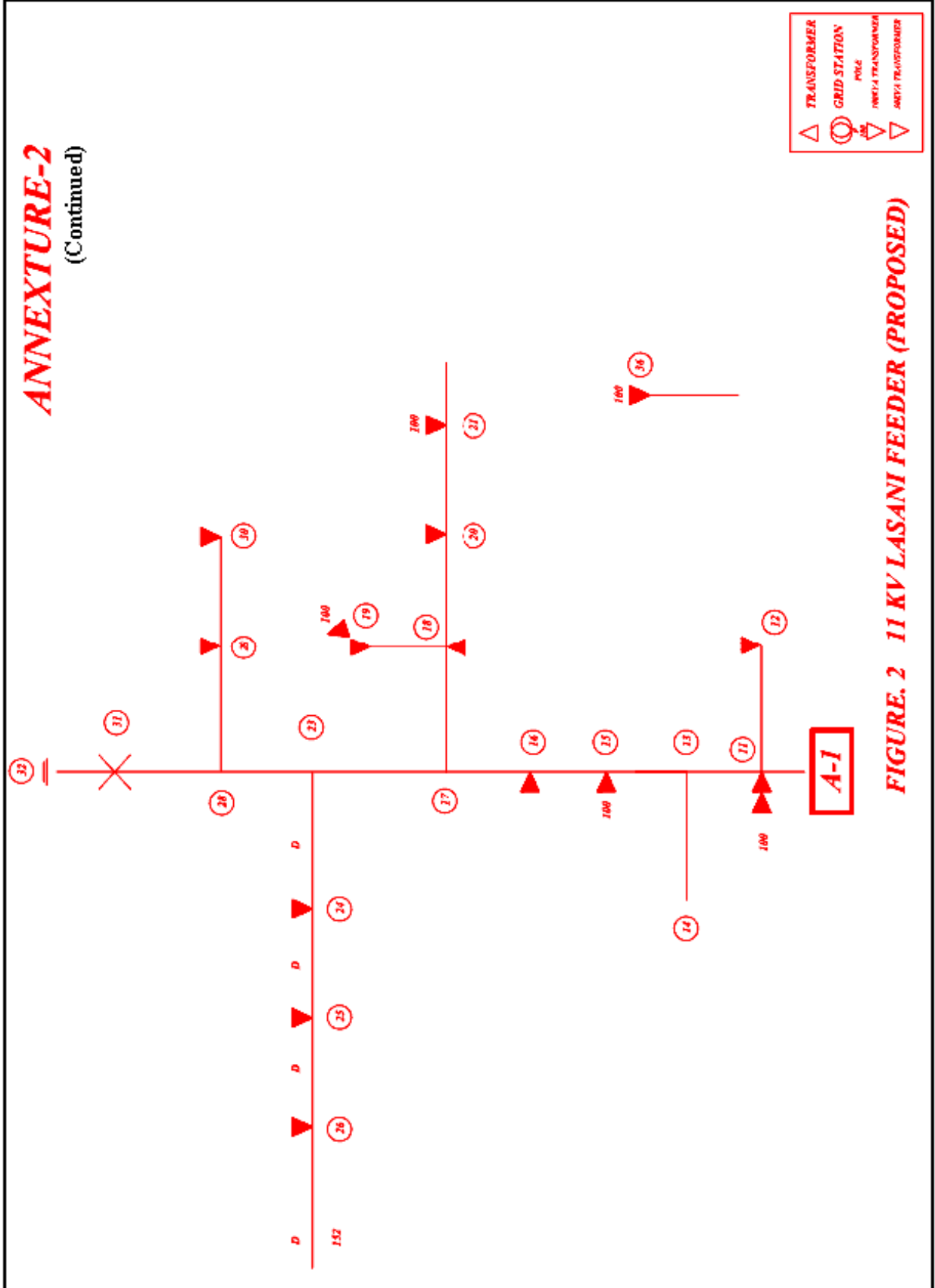
**ANNEXTURE-1**  
(Continued)



**FIGURE. 1 11 KV ANGOORI BAGH FEEDER (EXISTING)**

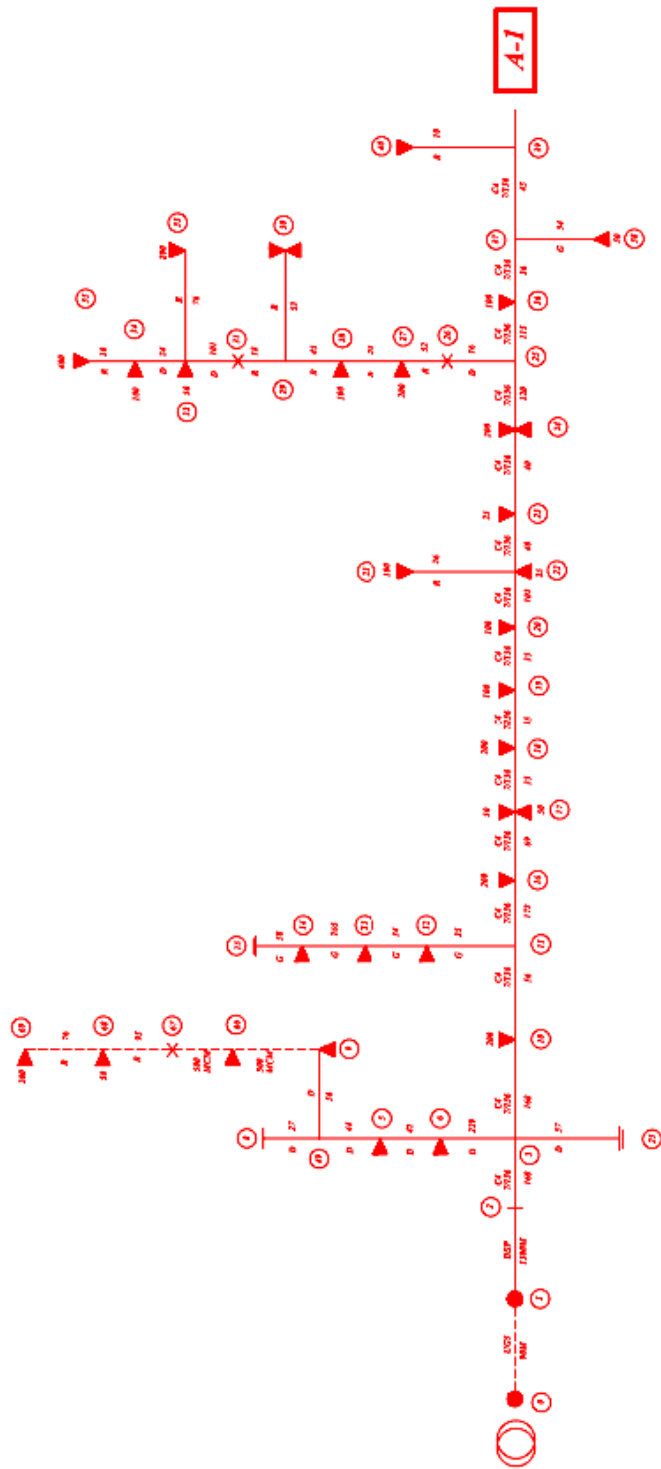


**ANNEXTURE-2**  
(Continued)



**FIGURE. 2 11 KV LASANI FEEDER (PROPOSED)**

**ANNEXTURE-3**



**FIGURE. 3 11 KV SABZI MANDI FEEDER (PROPOSED)**

**ANNEXTURE-3**  
(Continued)

