Design of Urban Distribution Feeders for Voltage Profile Improvement & Distribution Losses Reduction

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Abstract**:** India's power sector is characterised by inadequate and inefficient power supply. Since the country's independence, consumers are confronted with frequent power cuts, and fluctuating voltages and frequencies. In addition, system losses are high throughout India Transmission and distribution networks. In addition to these enormous direct losses, the indirect losses in terms of lost productivity and trade, sagging economic activity, rapidly shrinking of domestic and foreign investment in the power sector, uneconomical and misallocated investments in captive power, and reduced power generation could be many-fold. Distribution Sector requires economical system to provide electrical energy at a suitable prize and at a minimum voltage drop to reduce the voltage regulation. So, we require the economical way to provide the electrical energy by State Electricity Boards to various consumers at minimum voltage drop and reduce the regulation of voltage. Calculations & analysis will be required for load points, tie-points to select respective kVA capacity of transformers and hence the installation of suitable capacitor banks with proper locations for improvement of power factor and harmonics. This paper suggests the different methods of reduction of distribution losses in the 11kV urban distribution feeder to improve the voltage profile.

Keywords*: Distribution Sector, Punjab State Electricity Board, 11kV urban distribution feeder, ACSR conductors, voltage drop, voltage profile, coefficient of temperature rise and modulus of elasticity.*

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I. VOLTAGE DROP CALCULATION OF DISTRIBUTION FEEDERS

Distribution Sector requires economical system to provide electrical energy at a suitable prize and at a minimum voltage drop to reduce the voltage regulation. So, we require the economical way to provide the electrical energy by State Electricity Boards to various consumers at minimum voltage drop and reduce the regulation of voltage. The invisible energy which constitutes the flow of electrons on a closed circuit to do work is called electricity.

Need of electricity is because it is a form of energy which can be converted to any other form very easily. In the past, it was thought that the electricity is a matter which flows through the circuit to do work. However, now it has been established that electricity constitutes the flow of electrons in a circuit. In this process, the work is being done. So, every matter in space is electrical because it consists of electrons and protons in it. The manifestation of a form of energy probably due to separation & independent movement of certain parts of atoms called electrons. However, in the past, the consumption of electricity is prime motto, as it is available in lot with a capacity to do work, but as the time spent, now time is to conserve the electricity not to consume the electrical energy.

Electrical power system consists of various elements:-

- Generating Stations
- Substations
- Transmission Systems
- Distribution Systems
- Load Points.

Role of Transmission Lines The generators, transmission and distribution system of electrical power is called as power supply system. The transmission takes power from generating stations to transmission substations through the transmission lines which are to deliver bulk power from generating stations to load centres, beyond the economical service range of regular primary distribution lines. The transmission lines can be classified into Primary and Secondary lines. Primary transmission voltages are 110kV, 132kV, 220kV, 400kV and 765kV etc. depending upon the distance and amount of power to be transmitted, reliability. The secondary transmission voltage levels are 33kV or 66kV. HVDC system is upto ±600kV.

Role of transmission lines is to transmit bulk power from generating stations to large distance loads. Thus, the transmission lines are either

(i) Aerial Lines/Overhead Lines, (ii) Underground Cables and
(ii) Compressed Gas Insulated Lines.

The vast majority of world's power is of 3-Φ aerial lines design with bare conductors & with air as insulating medium around these conductors. For the transmission substations, power would be taken to sub-transmission substations at voltage level less than transmission voltage. This is chosen by economic consideration depend on distance and load.

Role of Distribution Lines is to deliver power from power stations or substations to load or consumers. For distribution of power, 3-phase, 4-wire AC system is usually adopted. Similarly the distribution system is either Primary or Secondary Distribution. The voltage level for primary distribution is 11kV, 6.6kV or 3.3kV etc. and the voltage level for secondary distribution is 415V for large industrial loads or 230V for small domestic loads. The size of secondary distribution is to be designed such that voltage at the last consumer premises the prescribed limit. The distribution system is further divided into

(i) Feeders, (ii) Distributors (iii) Supply Mains

Feeders are the conductors which connect the stations to areas to be fed by these stations. Generally from the feeders, no tappings are taken to consumers. So, current loading of a feeder remains the same along its length. It is based on its current carrying capacity. The feeders are generally at voltages 11kV or 33kV whereas Distributors are conductors that are taped throughout at all points where they are laid from substation transformers to various consumers in areas to be served. The main requirement of distributors is to supply the power to consumers.

II POWER SECTOR IN PUNJAB

Punjab State Electricity Board (PSEB), in its present form came into existence under Section 5 of the Electricity (Supply) Act-1948 on May 2, 1967 after the reorganization of the State. The Board was set up for generation, transmission and distribution of electricity in Punjab. The installed capacity of electricity in the State increased from 3524 MW to 1996-97 to 46409.38 MU in 2013-14 (4285.94 MU Hydel + 16306.27 MU Thermal). Thermal generation is 65% and hydro generation is 33% of the total electricity generated by the Board. The Board purchases about 25% of power available in the State. It served 52 Lakhs consumers by supplying 20192 million units of electricity in 2000-2001. The per capita consumption of Punjab state is 1291 kWh as on 31.12.2013. In 2012-13, the average cost of power supply per unit in Punjab state was 443 paise, which was the lowest in the country. The installed capacity generation in Punjab and year wise progress of transmission lines is as shown in table no. 1.1.

Sr. No.	Name of Project	Detail of Power machines with installed capacity (MW)	Share of Punjab (MW)	Generation during 2013-14 (MU)	Generation upto 31.12.2014 (MU)
1.	**OWN PROJECTS**				
a)	**Hydro Electric Projects**				
1.	Shanan PH	4x15+1x50=110.00	110	355.87	355.87
2.	UBDC	3x15+3x15.45=91.35	91.35	361.624	361.624
3.	Anandpur Sahib	4x33.5=134.00	314	735.00	735.00
4.	RSDHEP	4x150=600	452.4	1575.89	1575.89
5.	Mukerian	6x15+6x19.5=207.0	207	1246.74	1246.74
6.	Nadampur Micro	2x0.4=0.80	0.8	10.82	10.82
7.	Daudhar Micro	3x0.5=1.50	1.5		
8.	Rohti Micro	2x0.4=0.80.	0.8		
9.	Thuhi Micro	2x0.4=0.80	0.8		
10.	GGSSTP Ropar (Micro)		1.7		
	Total		1000.35	4285.94	4285.94
b)	**Thermal Projects**				
1.	GNDTP Bathinda	4x110=440.00	440	1635.46	2487.633
2.	GGSSTP, Ropar	6x210=1260.00	1260	8805.87	9984.65
3.	GHTP, Lehra Mohabat (Bathinda)	2x210+2x250=920.00	920	6664.994	6664.994
4.	RSTP, Jalkheri	1x10=10.00			
.	Total		2630	16306.27	16306.27
	Total (a + b)		3630	20592.21	20592.21
2.	Share from BBMM Projects		1161.00	4382.31	4382.31
3.	Share from Central Sector Projects		3071	20785.71	20785.71
4.	PEDA & Industrial Captive Plants installed in State		997	649.15	649.15
	Grand Total (1+2+3+4)		**8859.00**	**46409.38**	**46409.38**

Year wise Progress of Transmission Lines:

Sr. No.	Year	220kV Lines (ckm)	132kV Lines	66kV Lines	33/11kV Lines	Total
1.	1997-98	225.592	11.006	179.052	45.856	491.506
2.	1998-99	532.99	23.642	213.904	35.877	806.413
3.	1999-2000	132.736	15.422	237.542	35.678	421.378
4.	2000-01	281.977	42.393	212.495	39.518	576.383
5.	2001-02	111.35	13.286	177.043	48.578	350.257
6.	2002-03	129.405	24.057	44.01	10.783	204.345
7.	2003-04	137.915	14.971.	148.352	47.142	348.38
8.	2004-05	88.814	17.366	183.958	47.142	348.38
9.	2005-06	193.287	13.578	203.126	67.105	477.096
10.	2006-07	79.650	14.604	507.318	-	601.572
11.	2007-08	79.968	15.735	610.087	1.1489	707.937
12.	2008-09	158.654	13.167	436.768	1.900	610.489
13.	2009-10	14.590	21.424	138.610	-	174.624

Table No. 1.1: Installed capacity generation in Punjab and year wise progress of transmission lines in Punjab

Transmission and Distribution Losses in Punjab Transmission & distribution (T&D) losses of the Punjab State Electricity Board (PSEB) include unavoidable inherent in the process as well as avoidable ones due to poor engineering, poor maintenance and theft. The T&D losses in Punjab board are as under in table no. 1.2:-

Sr. No.	Description	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
1.	Energy losses (MU)	7416.03	8142.85	6063.938	7235.12	7306.70	7619.96
2.	%age of T&D losses	19.91 %	20.12 %	18.71 %	17.42 %	16.78 %	16.95%

Table No. 1.2 Year wise distribution of T& D losses in Punjab Electricity board

This shows that the losses in Punjab have been grossly underestimates. However, non-metering of agricultural supply makes it difficult to estimate T&D losses accurately. The above figures of losses are calculated annually by every state electricity boards.

III LITREATURE SEARCH

T&D losses represent a significant proportion of electricity losses in both developing and developed countries. The major portion of occurrence of T&D losses is the distribution systems of the states, which makes the gap large between the demand and supply of the electricity. Electric power providers have a duty to ensure that the consumers are always supplied with the required voltage level. However, the consumers at the extreme end of the feeders have been experiencing low voltage levels, for some time now, in all the countries. This is due to, in most cases, voltage drops is a major concern in low voltage distribution systems and not very particular about voltage drop in the high voltage sides leaving it unattended.

Soloman Nunoo et al in [1] presented a paper analysing the causes and effects of voltage drop on the 11KV GMC sub-transmission feeder in Tarkwa, Ghana. Studies showed that the voltage drop, total impedance, percentage efficiency and percentage regulation on the feeder are 944V, 4.56Ω, 91.79% and 8.94% respectively. Which all are beyond the acceptable limits. From the result, it is also realised that the causes of voltage drop on the feeder was mainly due to high impedance level as compared to the permissible value and this high impedance is caused by:-

(i) Poor jointing and terminations.
(ii) Use of undersized conductors.
(iii) Use of different types of conductor materials
(iv) Hot Spots etc.

The work concluded by proposing a number of solutions as well. In this paper, it was observed that the outage level of GMC Feeder is currently high of which stands at an average of ten times with a least duration of 10 minutes. These outages are mostly caused by:

(i) Over-grown of vegetation very close to the line, which comes in contact to the feeder in the events of strong winds.
(ii) Over-sagged conductors as a result of long spans between poles and
(iii) Obsolete headgear accessories, equipment and bent conductors.

Vujosevic, L. et al in [2] presented a paper estimating that the voltage drop in radial distribution networks can be applied for all voltage levels, therefore it was indicated in the work that in distribution system, voltage drop is the main indicator of power quality and it has a significant influence at normal working regime of electrical appliances, especially motors. This work was mainly focused on low voltage distribution system.

Konstantin et al in [3] presented a paper analyzing a power distribution line with high penetration of distributed generation and strong variation of power consumption and generation levels. In the presence of uncertainty the statistical description of the system is required to assess the risks of power outages. In order to find the probability of exceeding the constraints for voltage level and find the distribution by use of algorithm. The algorithm is based on the assumption of random but statistically distribution of loads on distribution lines. In the paper, the efficient implementation of the proposed algorithm suitable for large heterogeneous systems is a challenging task that requires a thoughtful selection of suitable the techniques of the power distribution system that would allow fast evaluation.

C.G. Carter-Brown et al in [4] presented a paper, in which a model is developed to calculate MV and LV voltage and voltage drop limits based on differential network-load combinations. The result of the model are suitable accurate for the calculation of guidelines for optimum voltage drop limits. Medium and low voltage (MV and LV) electricity distribution networks should supply customers at voltages within ranges that allow the efficient and economic operation of equipment and appliances. The permitted voltage variation is usually defined in regulations. Voltage variation is a key constraint in electricity weak networks and voltage management is applied to compensate for the voltage drop in the impedance of the distribution feeders through improving the load power factors or changing the effective ratio of the transformers and voltage regulators.

C.G. Carter-Brown et al in [5] presented a paper, which comprises of the various factors for voltage drop apportionment or voltage variation management in Eksom's distribution networks, in which voltage regulation is a term used to describe the variation of voltage.

C.G. Carter-Brown et al in [6] presented a paper, which consists of optimal voltage regulation limits and voltage drop apportionment in the distribution systems, in which the planner/ designer of a future network assumes the network will be operated in a reasonable manner (voltage control, tap settings, balanced loads and appropriate configuration of normally open points) and apportions the allowable voltage variation between the MV and LV terminals.

S.A. Qureshi et al in [7] presented a paper in his research to develop and guide lines for distribution engineers to show that by reducing the energy losses of the distribution systems available capacity of the system may be conserved without outing up additional capacity. A generalized computer program is used to evaluate any given HT/LT system and propose capacitor banks at different locations of feeders, 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.

Amin M. et al in [8] presented a paper in his research that WAPDA power system is heavily overloaded because the system has been expanded without proper planning and increasing the required level of capital expenditure. Due to this unplanned expansion in the system, the supply conditions were sacrificed to meet the required targets. Due to this over-increasing demand for power all around, the distribution system of WAPDA remains under pressure. The methodology to increase the capacity of the system was outlined as

(i) Data collection of given power distribution system.
(ii) Analysis of power distribution system at different loads, voltage levels, conductor sizes, current levels etc.
(iii) Designing of power distribution network by simulating on computer using feeder analysis software applicable in WAPDA for calculation of parameters of system such as power factor, voltage drops, power losses, cost involved with respect to benefits gained in specific period of time etc.
(iv) Calculation of exact rating of capacitors required to improve the power factor, length of conductor to be replaced with conductor size.
(v) Energy and cost saving through the system improvement.

Beg D. et al in [9] presented a paper, which comprises of that 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. Technical losses result from the nature and type of load, design of electrical installation/ equipment, layout of installations, poor maintenance of the system, under size and lengthy service lines, over-loading and sub-standard electrical equipments

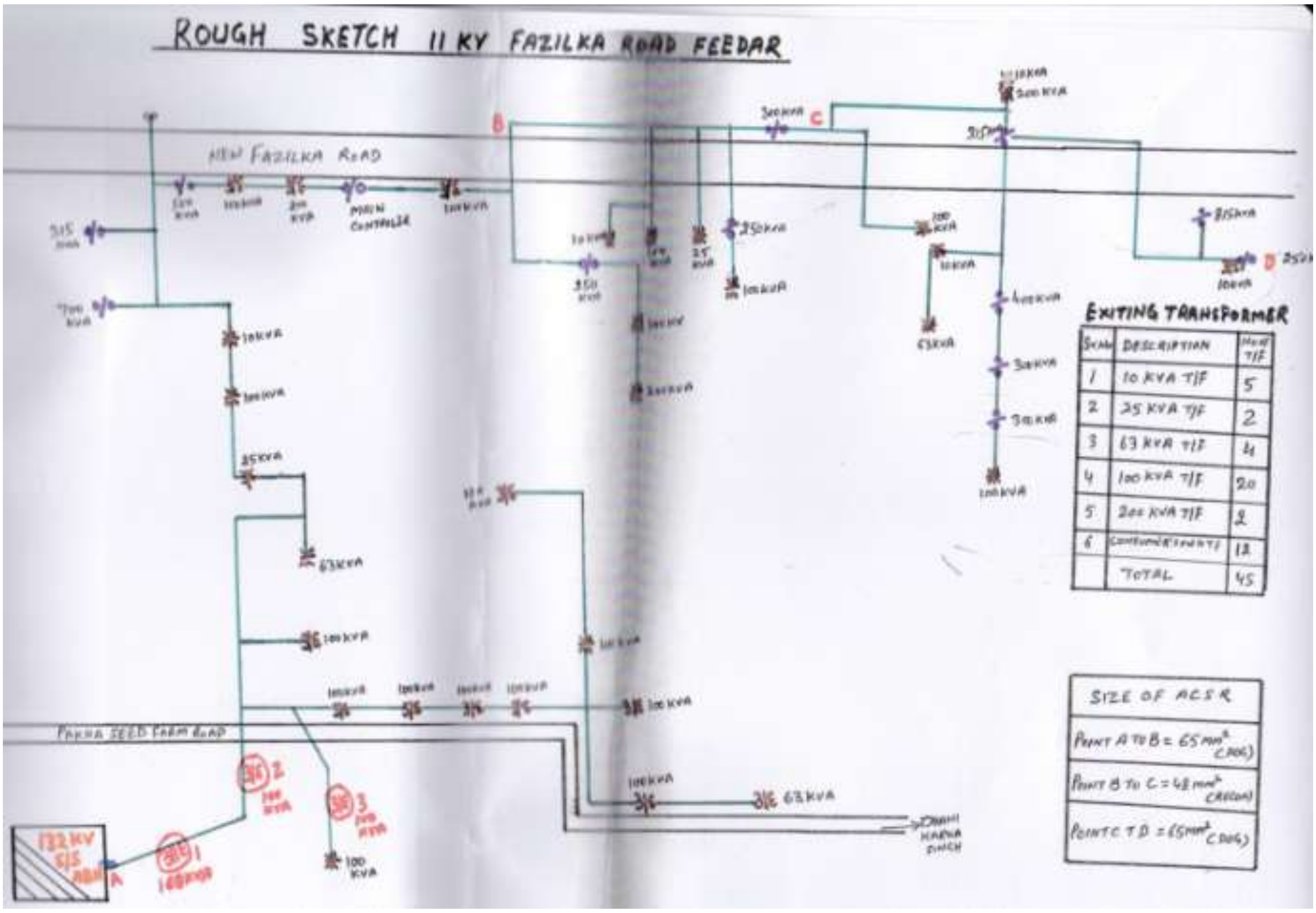
Sarang Pande et al in [10] presented a paper, in which a method for energy losses calculation is presented. This paper demonstrates the capability of Load factor and load loss factor to calculate the power losses of the network. The data used is readily available with the engineers of power Distribution Company. The results obtained can be used for financial loss calculation and can be presented to regulate the tariff determination process. The technical losses are the losses occurred in the electrical elements during of transmission of energy from source to consumer and mainly comprises of ohmic and iron losses.

Losses in an electrical power system can be classified into two categories

(i) Current depending losses
  a. Copper losses = $(\text{Current})^2$ x resistance
(ii) Voltage depending losses
  a. Iron losses of transformers
  b. Dielectric losses (insulation material)
  c. Losses due to corona.

IV. Voltage drop Calculation of Urban distribution feeder No. 1
11kV Fazilka Road Feeder

The single-line diagram of the 11kV Fazilka Road Feeder is obtained from Punjab State Power Cooperation Ltd. is available at fig. no. 1.1 and can be hereby redrawn on ETAP software:



Conductor Size = 65 mm^2 (DOG) **(See Annexure-I)**
Conductor Size = 48 mm^2 (RACCOON)
Resistance at 20^0C = 0.2745Ω
Resistance at 65^0C = 0.3242Ω
Resistance at 75^0C = 0.3353Ω

Data of Feeder

The data obtained from State Electricity Board of Subdivision is as under as shown in table no. 1.3

Sr. No.	From- To	ACSR size	kVA	Km	Factor	Voltage drop
1	AB	65mm^2	6322	0.772	0.0415	202.544
2.	BC	65mm^2	5359	0.160	0.0415	35.584
3.	CD	65mm^2	5259	0.470	0.0415	102.577
4.	DE	65mm^2	5196	0.464	0.0415	100.054
5.	E'E1	65mm^2	5171	0.240	0.0415	51.503
6.	E1E2	65mm^2	5071	0.798	0.0415	167.936
7.	E2F	65mm^2	5061	0.542	0.0415	113.837
8.	FG	65mm^2	4361	0.240	0.0415	43.436
9.	GH	65mm^2	4046	0.146	0.0415	24.515
10.	HI	65mm^2	3546	0.134	0.0415	19.719
11.	IJ	65mm^2	3446	0.145	0.0415	20.736
12.	JK	65mm^2	3246	0.052	0.0415	7.005
13.	KL	48mm^2	2533	0.740	0.0499	93.534
14.	LM	48mm^2	2423	0.100	0.0499	12.091
15.	MN	48mm^2	2398	0.026	0.0499	3.111
16.	NO	48mm^2	2048	0.140	0.0499	14.307
17.	OP	65mm^2	1948	0.654	0.0415	52.871
18.	PQ	65mm^2	1738	0.045	0.0415	3.246
19.	QR	65mm^2	1423	0.100	0.0415	5.905
20.	RS	65mm^2	1173	0.315	0.0415	15.334
21.	ST	65mm^2	250	0.045	0.0415	0.467
			Total Voltage drop			**1090.312**

Table No. 1.3 Voltage drop calculation data of 11kV Fazilka Road Feeder

Maximum Demand = 120 Amp.

$$\text{Demand Factor} = \frac{\sqrt{3} \times 11 \times \text{max. demand}}{\text{Total kVA}}$$

$$= \frac{\sqrt{3} \times 11 \times 120}{6322} = 0.362$$

Actual Voltage drop = Total voltage drop x demand factor

= 1090.312 x 0.362 =**394.30**

$$\%\ \text{voltage drop} = \frac{\text{Actual voltage drop}}{11000- \text{Actual voltage drop}} \times 100$$

$$\%\ \text{voltage drop} = \frac{394.30}{11000- 394.30} \times 100 = \mathbf{3.72}$$

Total circuit length of feeder = **6.328km**

On the basis of the above data, graph between the lengths of the various points on feeder versus voltage drop will be drawn in fig. no. 1.2.

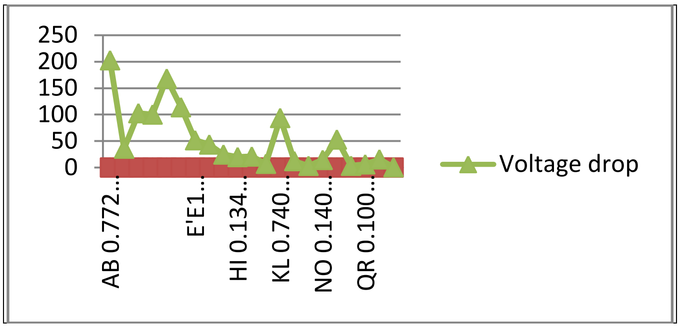


Fig. No. 1.2 Graph between length of feeder V/s Voltage drop

Estimation of Current in feeder lines

On the basis of the data of feeder, the calculation of current flowing through the feeder lines can be calculated as under in table no. 1.4.

Section	Length in km	Voltage Drop (Volts)	kVA	Current in feeder lines
AB	0.772	202.544	6322	331.82
BC	0.160	35.584	5359	281.27
CD	0.470	102.577	5259	276.03
DE	0.464	100.054	5196	272.72
E'E1	0.240	51.503	5171	271.41
E1E2	0.798	167.936	5071	266.16
E2F	0.542	113.837	5061	265.63
FG	0.240	43.436	4361	228.89
GH	0.146	24.515	4046	212.36
HI	0.134	19.719	3546	186.12
IJ	0.145	20.736	3446	180.87
JK	0.052	7.005	3246	170.37
KL	0.740	93.534	2533	132.95
LM	0.100	12.091	2423	127.17
MN	0.026	3.111	2398	125.86
NO	0.140	14.307	2048	107.49
OP	0.654	52.871	1948	102.24
PQ	0.045	3.246	1738	91.22
QR	0.100	5.905	1423	74.69
RS	0.315	15.334	1173	61.57
ST	0.045	0.467	250	13.12
Total	**6.328 km**	**1090.312**		

Table No. 1.4 Estimation of current in feeder line

From the above calculations, it is assumed that the current estimated on feeder line as reference current value at power factor of 0.88 (lagging).

Estimation of Current at different power factor:

On the basis of the current estimation at reference power factor of 0.88 (lagging), estimation of currents at other power factors, say 0.65 (lag) and unity power factor is also hereby calculated and is as under in table no. 1.5 on the basis of required expression.

$$\textbf{Current, I } \alpha \ \frac{1}{\cos \Phi}$$

Section	Current at 0.65 power factor	Current at 0.88 power factor (reference)	Current at unity power factor
AB	245.09	331.82	377.07
BC	208.20	281.27	319.63
CD	203.89	276.03	313.67
DE	201.44	272.72	309.91
E'E1	200.47	271.41	308.42
E1E2	196.60	266.16	302.45
E2F	196.20	265.63	301.85
FG	169.07	228.89	260.10
GH	156.86	212.36	241.32
HI	137.47	186.12	211.5
IJ	133.60	180.87	205.53
JK	125.84	170.37	193.60
KL	98.20	132.95	151.08
LM	93.93	127.17	144.51
MN	92.96	125.86	143.02
NO	79.39	107.49	122.15
OP	75.52	102.24	116.18
PQ	67.38	91.22	103.66
QR	55.17	74.69	84.87
RS	45.48	61.57	69.96
ST	9.69	13.12	14.91

Table No. 1.5 Calculation of currents in feeder at various power factors

V CALCULATION OF VOLTAGE DROP AT VARIOUS POWER FACTORS & TEMPERATURE

Now voltage drop can be estimated at various power factors and also at various temperatures of conductors.

At power factor 0.88 (reference) and at various temperature

Resistance at 20^0C = 0.2745Ω

Resistance at 65^0C = 0.3242Ω

Resistance at 75^0C = 0.3353Ω

On the basis of the above parameters, the voltage drop calculations had been estimated in table no. 1.6 at various temperatures i.e. 20^0C, 65^0C and at 75^0C

Section	Current at 0.88pf.	Voltage drop at 20^0C (reference)	Voltage drop at 65^0C	Voltage drop at 75^0C
AB	331.82	91.0846	107.57604	111.25925
BC	281.27	77.2086	91.187734	94.309831
CD	276.03	75.7702	89.488926	92.552859
DE	272.72	74.8616	88.415824	91.443016
E'E1	271.41	74.502	87.991122	91.003773
E1E2	266.16	73.0609	86.289072	89.243448
E2F	265.63	72.9154	86.117246	89.065739
FG	228.89	62.8303	74.206138	76.746817
GH	212.36	58.2928	68.847112	71.204308
HI	186.12	51.0899	60.340104	62.406036
IJ	180.87	49.6488	58.638054	60.645711
JK	170.37	46.7666	55.233954	57.125061
KL	132.95	36.4948	43.10239	44.578135
LM	127.17	34.9082	41.228514	42.640101
MN	125.86	34.5486	40.803812	42.200858
NO	107.49	29.506	34.848258	36.041397
OP	102.24	28.0649	33.146208	34.281072
PQ	91.22	25.0399	29.573524	30.586066
QR	74.69	20.5024	24.214498	25.043557
RS	61.57	16.901	19.960994	20.644421
ST	13.12	3.60144	4.253504	4.399136
		1037.59894	1225.463028	1267.420592

Table No. 1.6 Voltage drop calculation at power factor 0.88

The above calculation in table no. 1.6 is hereby plotted as graph below in fig. no. 1.3

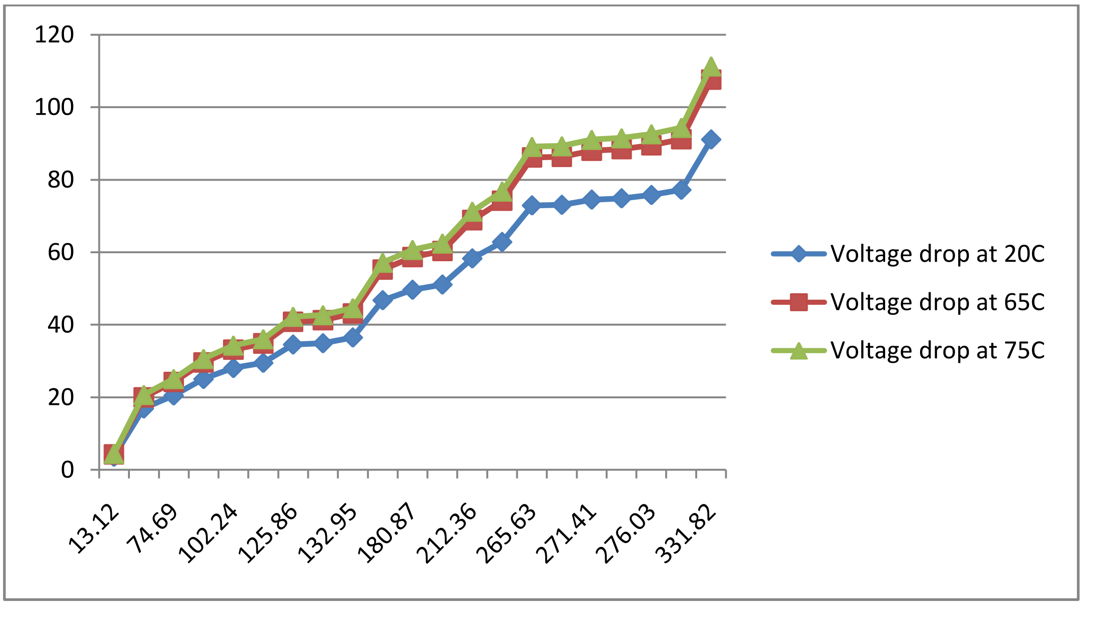


Fig. No. 1.3 Graph between Voltage drop Vs Current at 0.88 power factor

At power factor 0.65 (lagging) and at various temperature

Resistance at 20^0C = 0.2745Ω
Resistance at 65^0C = 0.3242Ω
Resistance at 75^0C = 0.3353Ω

On the basis of the above parameters, the voltage drop calculations had been estimated in table no. 1.7 at various temperatures i.e. 20^0C, 65^0C and at 75^0C

Section	Current at 0.65pf. (lag)	Voltage drop at 20^0C (reference)	Voltage drop at 65^0C	Voltage drop at 75^0C
AB	245.09	67.2772	79.458178	82.178677
BC	208.20	57.1509	67.49844	69.80946
CD	203.89	55.9678	66.101138	68.364317
DE	201.44	55.2953	65.306848	67.542832
E'E1	200.47	55.029	64.992374	67.217591
E1E2	196.60	53.9667	63.73772	65.91998
E2F	196.20	53.8569	63.60804	65.78586
FG	169.07	46.4097	54.812494	56.689171
GH	156.86	43.0581	50.854012	52.595158
HI	137.47	37.7355	44.567774	46.093691
IJ	133.60	36.6732	43.31312	44.79608
JK	125.84	34.5431	40.797328	42.194152
KL	98.20	26.9559	31.83644	32.92646
LM	93.93	25.7838	30.452106	31.494729
MN	92.96	25.5175	30.137632	31.169488
NO	79.39	21.7926	25.738238	26.619467
OP	75.52	20.7302	24.483584	25.321856
PQ	67.38	18.4958	21.844596	22.592514
QR	55.17	15.1442	17.886114	18.498501
RS	45.48	12.4843	14.744616	15.249444
ST	9.69	2.65991	3.141498	3.249057
		766.52761	905.31229	936.308485

Table No. 1.7 Voltage drop calculation at power factor 0.65 (lag)

The above calculation in table no. 1.7 is hereby plotted as graph below in fig. no. 1.4

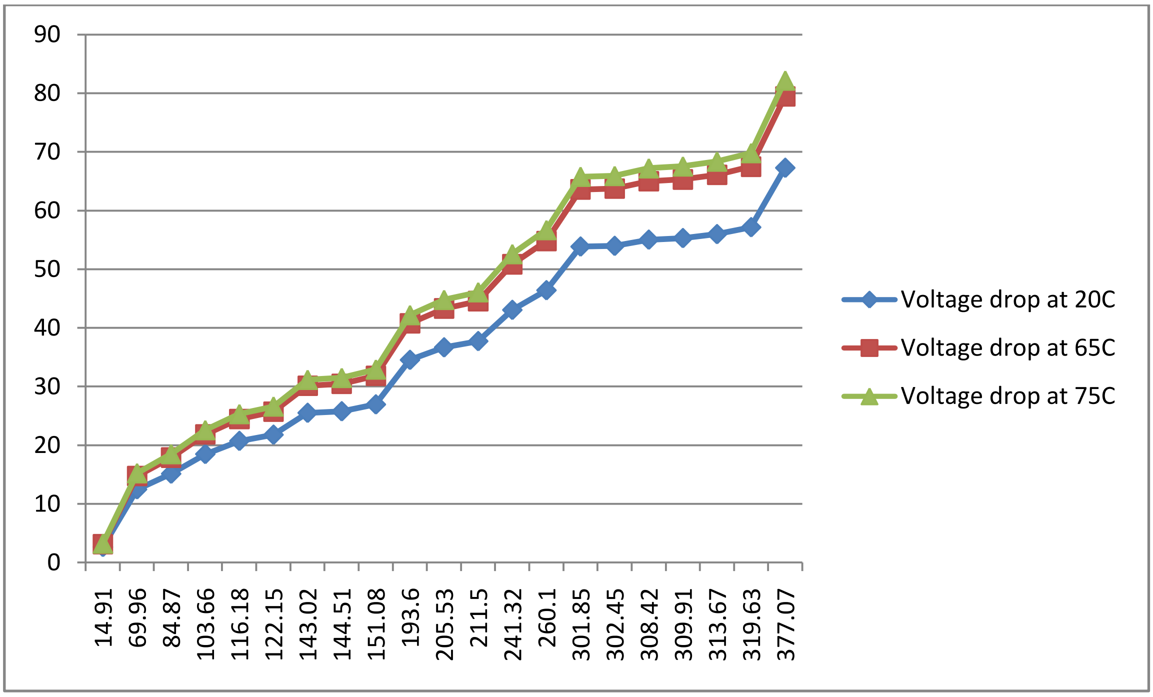


Fig. No. 1.4 Graph between Voltage drop Vs Current at 0.65 (lag) power factor

At power factor Unity and at various temperatures
Resistance at 20^0C = 0.2745Ω
Resistance at 65^0C = 0.3242Ω
Resistance at 75^0C = 0.3353Ω
On the basis of the above parameters, the voltage drop calculations had been estimated in table no. 1.8 at various temperatures i.e. 20^0C, 65^0C and at 75^0C

Section	Current at Unity pf.	Voltage drop at 20^0C (reference)	Voltage drop at 65^0C	Voltage drop at 75^0C
AB	377.07	67.2772	79.458178	82.178677
BC	319.63	57.1509	67.49844	69.80946
CD	313.67	55.9678	66.101138	68.364317
DE	309.91	55.2953	65.306848	67.542832
E’E1	308.42	55.029	64.992374	67.217591
E1E2	302.45	53.9667	63.73772	65.91998
E2F	301.85	53.8569	63.60804	65.78586
FG	260.10	46.4097	54.812494	56.689171
GH	241.32	43.0581	50.854012	52.595158
HI	211.5	37.7355	44.567774	46.093691
IJ	205.53	36.6732	43.31312	44.79608
JK	193.60	34.5431	40.797328	42.194152
KL	151.08	26.9559	31.83644	32.92646
LM	144.51	25.7838	30.452106	31.494729
MN	143.02	25.5175	30.137632	31.169488
NO	122.15	21.7926	25.738238	26.619467
OP	116.18	20.7302	24.483584	25.321856
PQ	103.66	18.4958	21.844596	22.592514
QR	84.87	15.1442	17.886114	18.498501
RS	69.96	12.4843	14.744616	15.249444
ST	14.91	2.65991	3.141498	3.249057
		766.52761	**905.31229**	**936.308485**

Table No. 1.8 Voltage drop calculation at Unity power factor

The above calculation in table no. 1.8 is hereby plotted as graph below in fig. no. 1.5

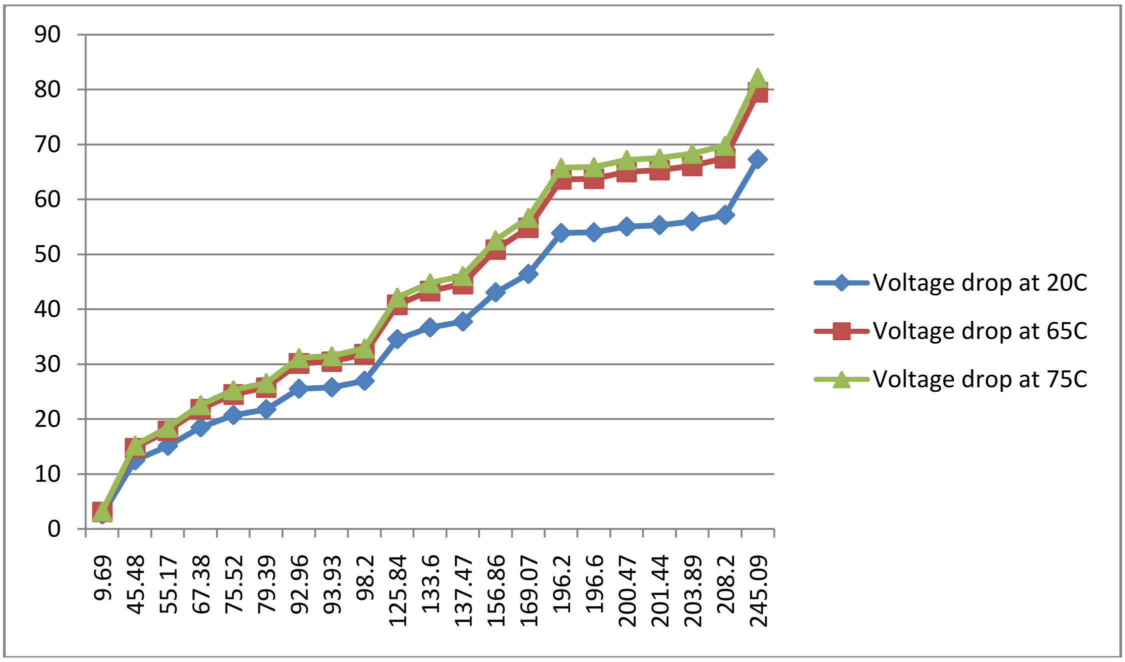


Fig. No. 1.5 Graph between Voltage drop Vs Current at Unity power factor

VI ALTERATION OF ACSR CONDUCTOR SIZE

Alteration of ACSR conductor means the size of conductor used for obtaining voltage profile in the distribution feeder can be modified, so that voltage will be reached at the end consumer will be within the limits as per desired norms.

Alteration of conductor with specific size

The size of conductor used in the 11kV feeder, which is 65mm^2 or 48mm^2, can be modified with 80mm^2 (LEOPARD).

Existing Conductor Size of feeder = 65mm^2 (DOG)
Proposed Conductor Size of feeder = 80mm^2 (LEOPARD)
Resistance at 20^{0}C of proposed conductor = 0.2193Ω
Resistance at 65^{0}C of proposed conductor = 0.2590Ω
Resistance at 75^{0}C of proposed conductor = 0.2679Ω

Thus, proposed voltage drops can be estimated at various power factors and also at various temperatures of conductors.

At power factor 0.88 (reference) and at various temperature

Resistance at 20^{0}C of proposed conductor = 0.2193Ω
Resistance at 65^{0}C of proposed conductor = 0.2590Ω
Resistance at 75^{0}C of proposed conductor = 0.2679Ω

On the basis of the above parameters, the proposed voltage drop calculations had been estimated in table no. 1.9 at various temperatures i.e. 20^{0}C, 65^{0}C and at 75^{0}C

Section	Current at 0.88pf.	Voltage drop at 20^{0}C (reference)	Voltage drop at 65^{0}C	Voltage drop at 75^{0}C
AB	331.82	72.768126	85.94138	88.894578
BC	281.27	61.682511	72.84893	94.309831
CD	276.03	60.533379	71.49177	94.309831
DE	272.72	59.807496	70.63448	92.552859
E'E1	271.41	59.520213	70.29519	91.443016
E1E2	266.16	58.368888	68.93544	91.003773
E2F	265.63	58.252659	68.79817	89.243448
FG	228.89	50.195577	59.28251	89.065739
GH	212.36	46.570548	55.00124	76.746817
HI	186.12	40.816116	48.20508	71.204308
IJ	180.87	39.664791	46.84533	62.406036
JK	170.37	37.362141	44.12583	60.645711
KL	132.95	29.155935	34.43405	57.125061
LM	127.17	27.888381	32.93703	44.578135
MN	125.86	27.601098	32.59774	42.640101
NO	107.49	23.572557	27.83991	42.200858
OP	102.24	22.421232	26.48016	36.041397
PQ	91.22	20.004546	23.62598	34.281072
QR	74.69	16.379517	19.34471	30.586066
RS	61.57	13.502301	15.94663	25.043557
ST	13.12	2.877216	3.39808	20.644421
		828.94523	**979.00964**	**1334.9666**

Table No. 1.9 Proposed Voltage drop calculation at power factor 0.88

The above calculation in table no. 1.9 is hereby plotted as graph below in fig. no. 1.6

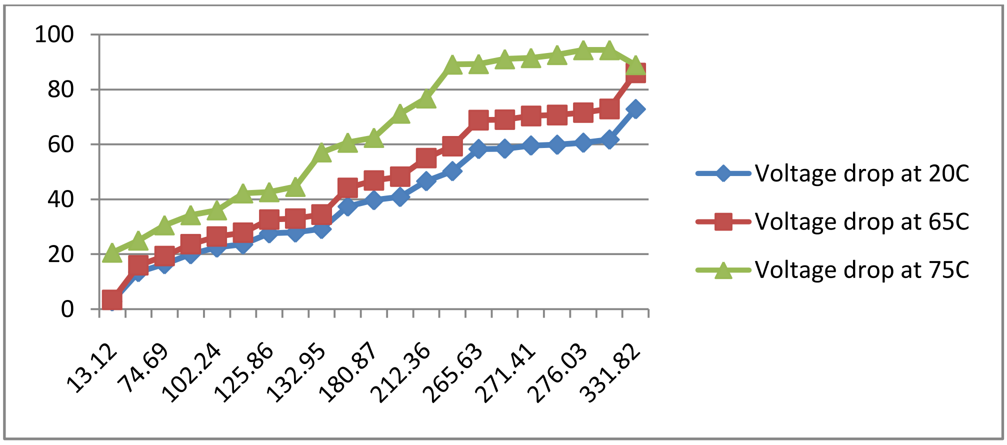


Fig. No. 1.6 Graph between proposed Voltage drop Vs Current at 0.88 power factor

At power factor 0.65 (lagging) and at various temperature

Resistance at 20^0C of proposed conductor = 0.2193Ω

Resistance at 65^0C of proposed conductor = 0.2590Ω

Resistance at 75^0C of proposed conductor = 0.2679Ω

On the basis of the above parameters, the voltage drop calculations had been estimated in table no. 1.10 at various temperatures i.e. 20^0C, 65^0C and at 75^0C

Section	Current at 0.65pf. (lag)	Voltage drop at 20^0C (reference)	Voltage drop at 65^0C	Voltage drop at 75^0C
AB	245.09	53.748237	63.47831	65.659611
BC	208.20	45.65826	53.9238	55.77678
CD	203.89	44.713077	52.80751	54.622131
DE	201.44	44.175792	52.17296	53.965776
E'E1	200.47	43.963071	51.92173	53.705913
E1E2	196.60	43.11438	50.9194	52.66914
E2F	196.20	43.02666	50.8158	52.56198
FG	169.07	37.077051	43.78913	45.293853
GH	156.86	34.399398	40.62674	42.022794
HI	137.47	30.147171	35.60473	36.828213
IJ	133.60	29.29848	34.6024	35.79144
JK	125.84	27.596712	32.59256	33.712536
KL	98.20	21.53526	25.4338	26.30778
LM	93.93	20.598849	24.32787	25.163847
MN	92.96	20.386128	24.07664	24.903984
NO	79.39	17.410227	20.56201	21.268581
OP	75.52	16.561536	19.55968	20.231808
PQ	67.38	14.776434	17.45142	18.051102
QR	55.17	12.098781	14.28903	14.780043
RS	45.48	9.973764	11.77932	12.184092
ST	9.69	2.125017	2.50971	2.595951
		612.38429	**723.24455**	**748.09736**

Table No. 1.10 Proposed Voltage drop calculation at power factor 0.65 (lag)

The above calculation in table no. 1.10 is hereby plotted as graph below in fig. no. 1.7

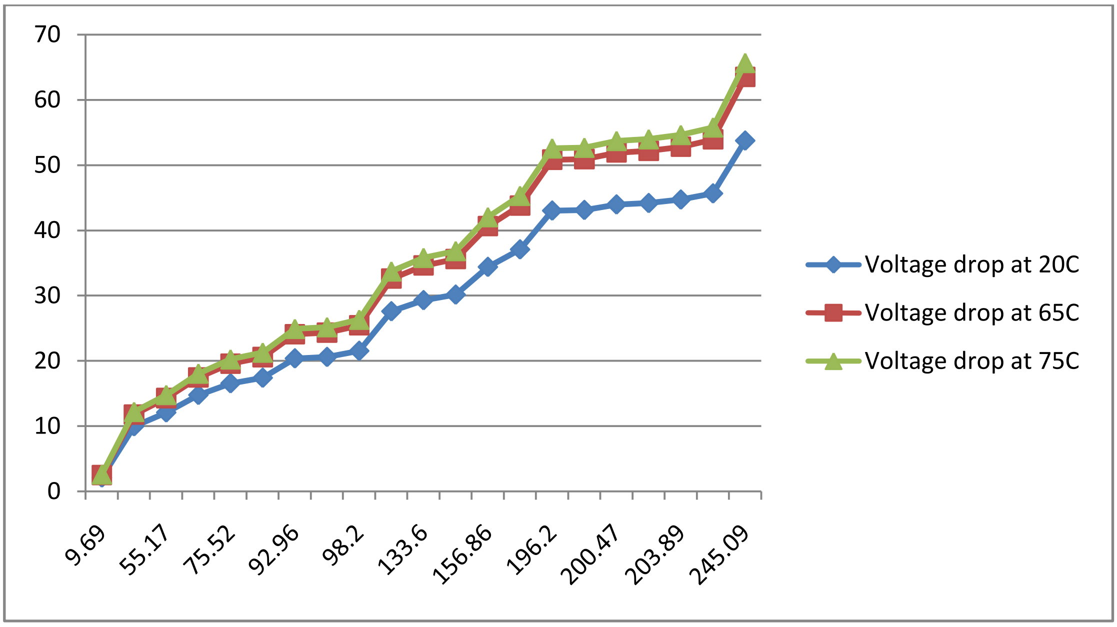


Fig. No. 1.7 Graph between proposed Voltage drop Vs Current at 0.65 (lag) power factor

At power factor Unity and at various temperatures

Resistance at 20^0C of proposed conductor = 0.2193Ω

Resistance at 65^0C of proposed conductor = 0.2590Ω

Resistance at 75^0C of proposed conductor = 0.2679Ω

On the basis of the above parameters, the voltage drop calculations had been estimated in table no. 1.11 at various temperatures i.e. 20^0C, 65^0C and at 75^0C

Section	Current at Unity pf.	Voltage drop at 20^0C (reference)	Voltage drop at 65^0C	Voltage drop at 75^0C
AB	377.07	82.691451	97.66113	101.01705
BC	319.63	70.094859	82.78417	85.628877
CD	313.67	68.787831	81.24053	84.032193
DE	309.91	67.963263	80.26669	83.024889
E'E1	308.42	67.636506	79.88078	82.625718
E1E2	302.45	66.327285	78.33455	81.026355
E2F	301.85	66.195705	78.17915	80.865615
FG	260.10	57.03993	67.3659	69.68079
GH	241.32	52.921476	62.50188	64.649628
HI	211.5	46.38195	54.7785	56.66085
IJ	205.53	45.072729	53.23227	55.061487
JK	193.60	42.45648	50.1424	51.86544
KL	151.08	33.131844	39.12972	40.474332
LM	144.51	31.691043	37.42809	38.714229
MN	143.02	31.364286	37.04218	38.315058
NO	122.15	26.787495	31.63685	32.723985
OP	116.18	25.478274	30.09062	31.124622
PQ	103.66	22.732638	26.84794	27.770514
QR	84.87	18.611991	21.98133	22.736673
RS	69.96	15.342228	18.11964	18.742284
ST	14.91	3.269763	3.86169	3.994389
		941.97903	**1112.506**	**1150.735**

Table No. 1.11 Proposed Voltage drop calculation at Unity power factor

The above calculation in table no. 1.11 is hereby plotted as graph below in fig. no. 1.8

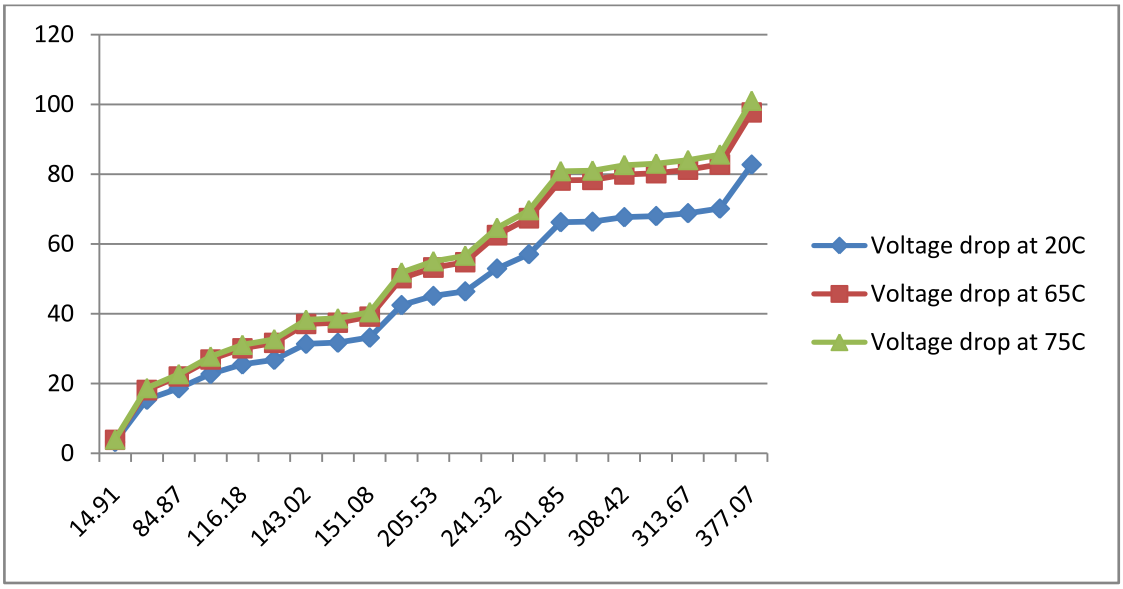


Fig. No. 1.8 Graph between proposed Voltage drop Vs Current at Unity power factor

VII CONCLUSION

Hence, it has been observed that the existing feeder is to be operated on 0.88power factor at a temperature range of conductor at 20^0C, however it is come to notice while analysing that the conductor size can be augmentated with 65mm^2 (DOG) and 48mm^2 (RACCOON) to the use of 80mm^2 (LEOPARD) and 50mm^2 (OTTER) for reduction of voltage drop in feeder, due to its better current carrying capacity of 375A in comparison of 324A of 65mm^2 conductor and same linear coefficient of temperature rise and modulus of elasticity, as observed from the diagram obtained after analysis.

But the weight of 80mm^2 conductor is 27.9mm^2 increased, which can be supported by the existing structures installed in the feeder area.

Location, proper placement and sizing of the capacitor banks for improving the power factors and harmonics in the 11 kV urban distribution feeders of the Subdivision can be investigated for improvement in system performance. Effects of High Voltage Distribution systems (HVDS) on the 11kV distribution feeders will be considered for better solutions. Effects of under sizing of the conductors was checked and recommendation for proper sizing of the conductors is hereby recommended for operation. Estimation of Hot spots will be checked and thus the performance will be enhanced and estimation of poor jointing and terminations will be another methodology for proper fault maintenance to be carried out.

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Annexure-I

Table: Aluminium Conductor Steel Reinforced [Based on IS: 398(1961)]

Conductor			Electrical properties		Stranding and Wire diameter				Mechanical Properties							
Code name	**Nominal cu area mm^2**	**Equivalent area of Al mm^2**	**Calculated resist. At 20^0C Ω/km**	**Approx. current carrying capacity 40^0C**	**Al. No.**	**Al. Dia.**	**Steel No.**	**Steel dia.**	**Conductor dia. mm**	**Conductor area mm^2**	**Total wt.**	**Wt. of Al.**	**Wt. of steel**	**Approx. Utl. Strength**	**Linear coeff. per ^{0}C x 10^{-6}**	**Modulus of elasticity kg/ cm^2 x 10^6**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
MOLE	6.5	10.47	2.71800	-	6	1.50	1	1.50	4.50	12.37	43	29	14	408	18.99	0.809
SQUIRREL	13	20.71	1.37400	115	6	2.11	1	2.11	6.33	24.48	85	58	27	771	18.99	0.809
GOPHER	16	25.91	1.09800	133	6	2.36	1	2.36	7.08	30.62	106	72	34	952	18.99	0.809
WEASEL	20	31.21	0.91160	150	6	2.59	1	2.59	7.77	36.88	128	87	41	1136	18.99	0.809
FERRET	25	41.87	0.67950	181	6	3.00	1	3.00	9.00	49.48	171	116	55	1503	18.99	0.809
RABBIT	30	52.21	0.544+0	208	6	3.35	1	3.35	10.05	61.71	214	145	69	1860	18.99	0.809
MINK	40	62.32	0.45650	234	6	3.66	1	3.66	10.98	73.65	255	172	82	2208	18.99	0.809
HORSE	42	71.58	0.39770	-	12	2.79	7	2.79	13.95	116.20	542	204	338	6108	15.30	1.070
BEAVER	45	74.07	0.38410	261	6	3.99	1	3.99	11.97	87.53	303	205	98	2613	18.99	0.809
RACCOON	48	77.83	0.3646	270	6	4.09	1	4.09	12.27	91.97	218	215	103	2746	18.99	0.809
OTTER	50	82.85	0.34340	281	6	4.22	1	4.22	12.66	97.91	339	230	109	2923	18.99	0.809
CAT	55	94.21	0.30200	305	6	4.50	1	4.50	13.50	111.30	385	261	125	3324	18.99	0.809

DOG	65	103.60	0.27450	324	6	4.72	7	1.57	14.16	118.50	394	288	109	2399	19.53	0.735
LEOPARD	80	129.70	0.21930	375	6	5.28	7	1.76	15.84	148.40	493	360	133	4137	19.53	0.735
COYOTE	80	128.50	0.22140	375	26	2.51	7	1.90	15.86	151.60	521	365	156	4638	18.99	0.773
TIGER	80	128.10	0.22210	382	30	2.36	7	2.36	16.52	161.80	604	363	241	5758	17.73	0.787
WOLF	95	154.30	0.18440	430	30	2.59	7	2.59	1.13	195.00	727	436	291	6880	17.73	0.787
LYNX	110	179.00	0.15890	475	30	2.79	7	2.79	19.53	226.20	844	506	338	7950	17.73	0.787
PANTHER	130	207.00	0.13750	520	30	3.00	7	3.00	21.00	261.60	976	586	390	9127	17.73	0.787
LION	140	232.30	0.12230	555	30	3.18	7	3.18	22.26	293.90	1097	659	438	10210	17.73	0.787
BEAR	160	258.10	0.11020	292	30	3.35	7	3.35	23.45	326.10	.1219	734	485	11310	17.73	0.787
GOAT	185	316.50	0.08989	680	30	3.71	7	3.71	25.97	400.00	1492	896	596	13780	17.73	0.787
SHEEP	225	366.10	0.07771	745	30	3.99	7	3.99	27.93	462.60	1726	1036	690	15910	17.73	0.787
KUNDAH	250	394.40	0.07434	-	42	3.50	7	1.94	26.82	424.80	1282	1120	162	9002	21.42	0.646
DEER	260	419.30	0.06786	806	30	4.27	7	4.27	29.89	529.40	1977	1188	789	18230	17.73	0.787
ZEBRA	260	418.60	0.06800	795	54	3.18	7	3.18	28.62	484.50	1623	1185	438	13316	19.35	0.686
ELK	300	465.70	0.06110	860	30	4.50	7	4.50	31.50	588.40	2196	1320	876	20240	17.73	0.787
CAMEL	300	464.50	0.06125	-	54	3.35	7	3.35	30.15	537.70	1804	1318	486	14750	19.36	0.686
MOOSE	325	515.70	0.05517	900	54	3.53	7	3.53	3177	597.11	2002	1463	539	16250	19.53	0.686
SPARROW	20	33.16	0.85780	-	6	2.67	1	2.67	8.01	39.22	135	92	43	1208	18.99	0.809
FOX	22	36.21	0.78570	165	6	2.79	1	2.79	9.37	42.92	149	101	48	1313	18.99	0.809