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Analysis of Technical Power Losses by Supervisory Control and Data Acquisition Load Flow Techniques

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ABSTRACT

This paper is an attempt to reduce the technical power losses in real time electricity distribution control system. The electricity distribution control system faces a major problem of distribution losses. However, the electricity power system faces major constraints which are inadequate size of conductor, cable, long distribution lines, failure of sub-station equipments, improper earth-lings, transformer failure, etc. Consequently, the main objective of this paper is to calculate the technical power losses in power transformers, distribution transformers, distribution line networks and also to calculate the % voltage regulation in 11 KV Monroe feeders of Chennai electricity distribution control centre-SCADA networks. The benefit of this paper is to improve the power factor and reduce the voltage drop at the tail-end of distribution feeder network has been carried out. In this study of sample survey was conducted based on constitution of Indian Electricity Act-2003 and follow-up of Tamil Nadu Electricity Board Rules and Regulations [1].

Keywords: Distribution Transformer losses, Line losses, Load factor, Load loss factor, Load curve, Load duration curve, load bifurcation and Voltage Regulation.

1. INTRODUCTION

The Chennai electricity distribution control centre is configured with group of ring main feeders with various voltage levels of 400 KV, 230 KV, 110 KV, 33 KV, 11 KV and Low Tension lines, which can be mutually interlinked with several back feeding arrangements. The technical power losses occurred in the electricity distribution system is more than 75% in secondary distribution utilities. To reduce the technical power losses in distribution system various techniques are involved as follows.

The annual energy losses are calculated in 11KV feeders with three different sizes of 120 sqmm, 240 sqmm and 300 sqmm cable networks with a pair of 10 MVA and single 20 MVA power transformers in terms of Million Units (MU) using load and load duration curve [2]. The losses in existing Transmission and Distribution (T&D) line systems are reduced by transferring the stained overloaded distribution networks in to adjoining under-loaded distribution networks from peak period to off-peak period [3]. The T&D losses in electric power circuits are reduced by replacing the existing overhead conductors in to underground cable systems, also the higher capacity distribution transformers are replaced to smaller rating distribution transformers installed nearer to consumer load centre by load bifurcation methods [4]. The evaluation of standard losses in distribution transformers using feeder No: 12 at 220/22 KV Sub-station, Pune City and India by actual and analytical reading methods are described [5]. The reduction of energy losses in existing LT distribution networks and proposed LT-less distribution networks are evaluated using Turbo C++ programming language [6]. The causes of higher distribution losses and subsequent loss rectification techniques are discussed. Then, the existing higher capacity distribution

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transformer loads are bifurcated in to smaller ratings of distribution transformers for installing nearby consumers load centre are discussed [7].

In this paper, SCADA load flow techniques are described for future expansion of the existing Chennai Electricity Distribution Control (CEDCC) network. The technical power losses are calculated from power transformers, distribution transformers and distribution line networks. The % voltage regulation is also achieved by 11 KV Monroe feeders of Chennai Electricity Distribution Control Centre networks.

2. IMPLEMENTATION OF SCADA LOAD FLOW TECHNIQUES

The implementation of Chennai electricity distribution control centre-SCADA load flow techniques comprises of the magnitudes of voltage, current, phase angle, real and reactive power flow in transmission and distribution line networks. Besides, thus losses in Mega Watt (MW) and Mega Volt Amps reactive (MVAr) are also specified. This information is essential for the calculation of technical power losses in distribution networks by using Gauss-Seidal and Newton–Raphson Methods aided by Electrical Transient and Analysis Program (ETAP).

3. LOSS CALCULATION APPROACH

3.1. Load Factor (LF)

It is defined as the ratio of average load to the maximum demand in KVA during a certain period of day/ month/ year.

$$LF = \frac{\text{KVA average}}{\text{KVA maximumdemand.}} \quad (1)$$

3.2. Load Loss Factor (LLF)

The ratio of actual energy losses during a designated period to the maximum current drawn at designated period is called Load Loss Factor.

$$LLF = \frac{\text{Actual losses during Period}}{\text{Maximum Current on designated period}} \quad (2)$$

The relationship between the LF and LLF as shown in given below:

$$LLF = K * LF + (1 - K) * LF^2 \quad (3)$$

Otherwise

$$LLF = 0.727 * LF^2 + 0.273 * (LF - K)^2 \quad (4)$$

Where K = coefficient of the load.

$$K = \frac{KVA_{\min}}{KVA_{\max}}$$

3.3. Losses in Feeder Circuit

The calculated energy losses in feeder circuit per annum using SCADA telemeter values is given by

$$\text{Losses in feeder circuits} = \frac{3 * I^2 * R * L * LLF * 8760}{10^6} \quad (5)$$

Where

I = Load, Amps

R = Resistance of Conductor, ohms/kilometre

L = Length of feeder, kilometres

3.4. Voltage Drop Calculation

The % voltage regulation is the difference in voltage between sending ends to receiving ends with respect to its receiving end voltage. The voltage drop calculations of 11 KV Monroe feeder in a 110 KV Chindradripet sub-station is

$$\text{Voltage Drop} = \frac{1.732*(R\cos\Phi + X\sin\Phi)*I}{No.of conductors/phase}*L \quad (6)$$

$$\text{Load Current I} = \frac{Active \quad Power}{(1.732*V*PF)} \quad (7)$$

$$\%\ \text{Voltage regulation} = \left(\frac{Vs - Vr}{Vr}\right)*100 \quad (8)$$

Where

X = Reactance of Conductor (or) Cable, Ohms

V_s = Sending end Voltage, Volts

V_r = Receiving end Voltage, Volts

4. POWER TRANSFORMER AND FEEDER CIRCUITS OF 110KV CHINDADRIPET SS

The electrical energy is received from generating station to sub-station and finally to the end user at various voltages levels of EHT to LT feeder network. For this analysis, 110 KV Sub-Station located in Chindadripet, Chennai Electricity Distribution Circle (CEDC), Chennai and India.

In this 110 KV Chindadripet grid sub-station, the incoming supply is received from 230 KV Tondiarpet sub-station and 110 KV Vyasarpadi sub-station. The incoming supply feeds a pair of 110/33 KV-50 MVA power transformers I and II, which is stepped-down in to two identical 33/11KV-2X16 MVA Power transformers I and II. Moreover, eight numbers 11 KV feeder circuits are connected in parallel to 16 MVA power transformers LV1 and LV2. The analysis of technical power losses in both of 16 MVA power transformers I and II with three numbers of 11 KV feeders are considered. Over these, one of the 11 KV Monroe feeders is considered to find out % voltage regulation using SCADA MFT (Multi Function Transducer) telemeter values. A typical 110 KV Chindadripet sub-station is shown in Fig. 1.

5. LOAD AND LOAD DURATION CURVE FOR 11KV FEEDER AND POWER TRANSFORMERS

The case study shows the calculation of technical power losses in three numbers 11 KV feeders (Monroe, ECR and Local) and a pair of 16 MVA Power Transformer I and II at 110 KV Chindadripet sub-station in Chennai Electricity Distribution Control Centre, Chennai and India. Using the above formula, losses in the Power Transformer and Distribution Transformers, feeder circuits and % voltage regulation in 11 KV Monroe feeder circuits before and after improvements by load bifurcation works are carried out. The load and its load duration curve represents the actual demand of power utilization for period 30 days duration

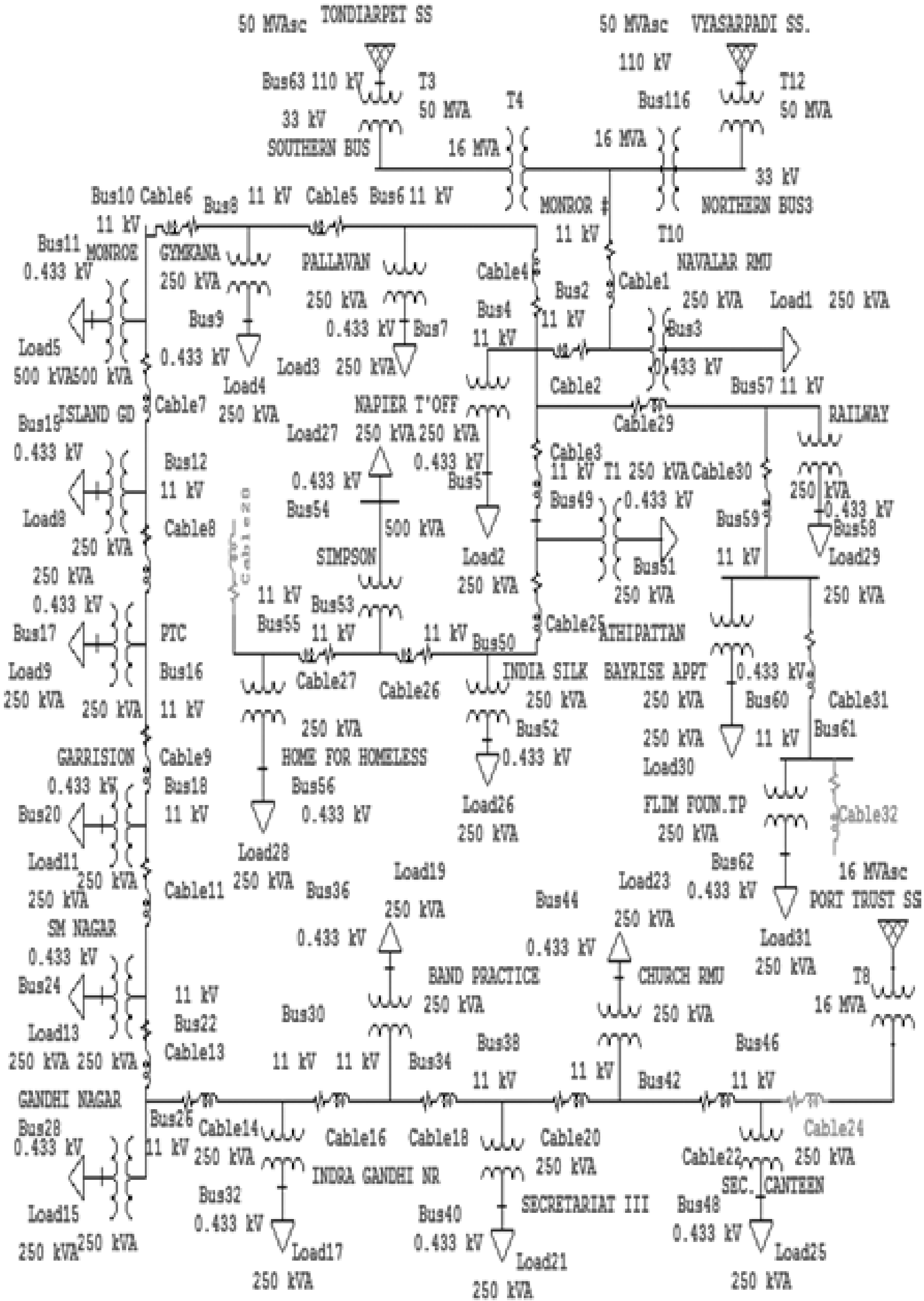

Figure 1: Typical configuration of 110 KV Chindadripet sub-station power transformers with 11 KV Monroe feeders

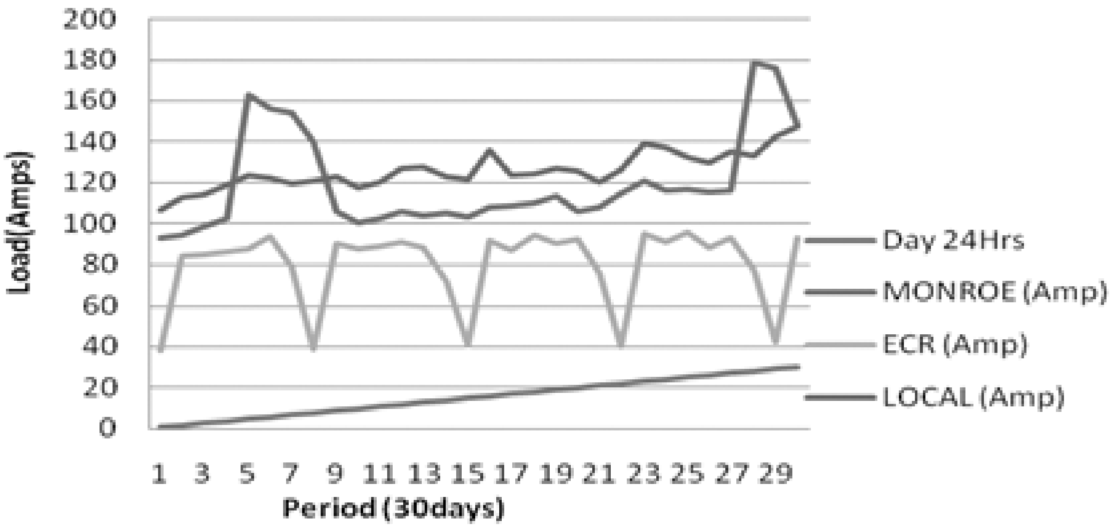

Figure 2: 3X 11 KV feeder-Load duration curve Vs Load current

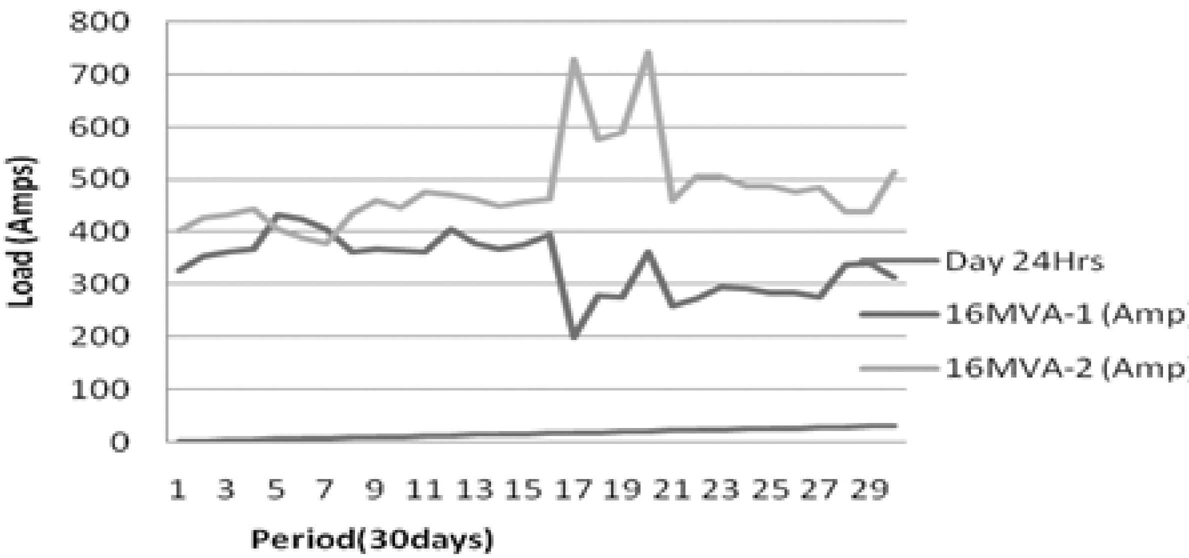

Figure 3: 2X16 MVA power transformer I and II-Load duration curve Vs Load current

for three numbers 11 KV feeder as shown in Fig. 2. and pair of 16 MVA power transformers I and II as shown in Fig. 3.

Technical power losses in feeder circuits in **MU** is calculated using equation (5)

11 KV feeder losses = $3 * I^2 * R * L * LLF * 24 * 30 * 10^{-6}$

Likely, technical losses in Power Transformer in **MU** is determined using equation (9)

$$\text{Power Transformer losses} = \frac{Noload.loss + [(\%Loading)^2 * Rated\_Copperloss * LLF] * 8760}{10^6} \quad (9)$$

6. PROPOSED LOAD BIFURCATION WORK

To calculate the technical power losses in a pair of power transformers (I and II), twenty two numbers distribution transformers and three numbers 11 KV feeders (Monroe #, ECR # & Local #) are calculated as shown in Table.2. and Table.3. The energy meter reading observed from Table.1. and calculation of existing voltage regulation in 11 KV Monroe feeder circuits as shown in Table.4. As per the Indian Electricity Act-

Table 1
Average Load details in 11 KV feeder and power transformer

Period	Feeder Name and Transformer Load in Amp				
Day	MONROE	ECR	LOCAL	16MVA-1	16MVA-2
1	93	38.4	106.8	327.6	405.00
2	94.2	84.3	112.5	353.7	429.30
3	98.7	84.9	114	361.8	433.80
4	102.3	86.4	118.8	367.2	444.60
5	163.2	87.6	123.6	432.9	405.90
6	156.6	94.2	122.1	425.7	391.50
7	154.2	78.9	119.4	405	379.80
8	139.8	39	120.6	362.7	437.40
9	106.2	90.6	123	366.3	461.70
10	100.8	87.6	117.3	363.6	448.20
11	102.6	89.4	120	360.9	476.10
12	105.6	91.5	127.2	406.8	471.60
13	104.1	88.5	127.5	379.8	462.60
14	105.3	72.3	123	368.1	450.00
15	102.9	40.8	121.5	376.2	459.00
16	108.3	91.8	135.9	394.2	464.40
17	108.9	87.3	123.3	198.9	728.10
18	110.1	94.8	124.5	279	576.90
19	113.4	90.3	126.6	275.4	591.30
20	106.2	92.7	125.4	360.9	741.60
21	108.3	76.5	120.3	260.1	461.70
22	114.9	40.2	126.3	273.6	505.80
23	120.9	95.1	138.9	294.3	507.60
24	116.4	91.2	137.1	290.7	486.90
25	117	96	132	283.5	486.90
26	115.2	88.8	129.3	282.6	477.00
27	116.4	93.6	134.7	276.3	484.20
28	178.8	78	133.2	338.4	438.20
29	176	42.3	142.2	340.2	438.30
30	148.2	93	147	313.2	513.90

Table 2
Technical power losses in 11 KV Monroe#, 11 KV ECR # & 11 KV Local # before load bifurcation

Before Load Bifurcation: Technical losses in Feeder Circuit						
11KV Feeder name	MONROE		ECR		LOCAL	
Lengh of Cable	13.5	KM	4.5	KM	6.20	KM
Peak Load	178.8	Amp	96	Amp	147.00	Amp
Average Load	120		80		125.80	
Load Factor	0.67		0.84		0.86	
Load loss Factor(0.20)	0.49		0.73		0.76	
Technical losses in Feeders	0.654	MU	0.09	MU	0.31	MU

Table 3
Technical power losses in power transformer I, II and distribution transformers before load bifurcation

Before Load Bifurcation: Technical losses in Transformer							
Technical loss for Power transformer={No Load loss+[(% of Loading)^2 *Rated Cu loss]}*LLF*24*365*10^{-6}							
Description of Calculation	Power and DistributionTransformer						
Transformer Capacity	16	16	MVA	100	250.00	500	KVA
Full Load Capacity	840	840	Amp	84	210.00	420	Amp
Transformer 11KV Peak Load	432.9	742	Amp	79.8	157.50	273	Amp
% of Peak Load	0.52	0.88	%	0.95	0.75	0.65	%
Load Factor	0.78	0.65		0.48	0.38	0.33	
Load loss Factor(0.20)	0.65	0.47		0.28	0.19	0.15	
Standard losses of Transformer							
No Load losses	16.8	16.8	KW	0.3	0.50	0.9	KW
Full(Cu) Load losses	68	68	KW	1.2	2.00	3.5	KW
Technical losses in Power Transformer in MU	0.198	0.29	MU	0.01	0.05	0.01	MU

Table 4
Voltage regulation in 11 KV Monroe feeders before load bifurcation

Before Load Bifurcation: Voltage Regulation in Feeder Circuit							
SL. NO	11 KV CABLE	Distance in KM	Distribution Transforme	Capacity in KVA	Cumulative Load	Momentu m	%Regulation
			BRANCH-1				
0	3x120	0.92	Chindadripe		7250	6670	1.72
1	3x120	0.82	NAVALAR	250	7250	5945	1.54
2	3x120	0.78	NAPIER	250	7000	6475	1.67
3	3x120	0.68	PALLAVAN	250	4000	2720	0.70
4	3x120	0.56	GYMKANA	250	3750	2100	0.54
5	3x120	0.49	MONROE	500	3500	1715	0.44
6	3x120	0.60	ISLAND RMU	250	3000	1800	0.47
7	3x120	0.42	PTC T'FF	250	2750	1155	0.30
8	3x120	0.62	GARRISION	250	2500	1550	0.40
9	3x120	0.42	S.M.NR RMU	250	2250	945	0.24
10	3x120	0.57	GANDHI NR	250	2000	1140	0.29
11	3x120	0.45	INDRA GI NR	250	1750	788	0.20
12	3x120	0.42	BAND	250	1500	630	0.16
13	3x120	0.60	SECRETRAIT	500	1250	750	0.19
14	3x120	0.51	CHURCH	250	750	383	0.10
15	3x120	0.60	SECRETRAIT	500	500	300	0.78
			BRANCH-2				
16	3x120	0.35	CALLTAX	250	2000	700	0.18
17	3x120	0.38	ATHIPATTAN	750	1750	665	0.17
18	3x120	0.50	INDIA SILK	500	1000	500	0.13
19	3x120	0.50	SIMPSON	250	500	250	0.06
20	3x120	0.60	HOME FOR	250	250	150	0.04
21	3x120	0.42	3,PALLAVAN	500	500	210	0.05
			BRANCH-3				
22	3x120	0.42	RAILWAY	250	750	315	0.08
23	3x120	0.50	BAYRISE	250	500	250	0.06
24	3x120	0.37	FIRM FOUND	250	250	93	0.02
	Total	**13.50**					**10.57**

2003, maximum permissible voltage regulation in 11 KV feeders is 9%, without diversity factor adapted condition. In this circumference, 11 KV Monroe feeder loads are compulsorily bifurcated to adjoining under loaded 11 KV feeder circuits. After releasing nine numbers distribution transformer from 11 KV Monroe feeder circuit's three numbers distribution transformer loads are accommodated to 11 KV ECR feeder and six numbers distribution transformer loads are accommodated to 11 KV Local feeder. After load bifurcation, reduced length of 11 KV Monroe feeders is 13.50 to 9.46 kilometres with reduced cumulative loads from 7250 to 4250 KVA, the calculated energy losses in power transformers, distribution transformers and 11 KV feeder circuits are tabulated in Table. 5, Table.6. and Table.7.

Finally the reduced voltage regulation in 11 KV Monroe feeders is 10.57 to 6.75% after load bifurcation as shown in Table.7. All the real time values are implemented in ETAP software program to get energy losses in MW, MVAr and Voltage drop at each and every point of nodes as shown in Figure.5. and Table.8. The Nett calculated energy losses in power transformers, distribution transformers and 11 KV feeder circuits are obtained as shown in Table.9. A comparison statement is obtained from practical values and Theoretical values in 11 KV Monroe Feeder circuits are shown in Figure.6.

Table 5
Technical power losses in 11 KV Monroe#, 11 KV ECR# & 11 KV Local# after load bifurcation

After Load Bifurcation: Technical losses in Transformer							
Technical loss for Power transformer={No Load loss+[(% of Loading)^2 *Rated Cu loss]}*LLF*24*365*10^{-6}							
Description of Calculation	Power and DistributionTransformer						
Transformer Capacity	16	16	MVA	100	250.00	500	KVA
Full Load Capacity	840	840	Amp	84	210.00	420	Amp
Transformer 11KV Peak Load	432.9	742	Amp	79.8	157.50	273	Amp
% of Peak Load	0.52	0.88	%	0.95	0.75	0.65	%
Load Factor	0.78	0.65		0.48	0.38	0.33	
Load loss Factor(0.20)	0.65	0.47		0.28	0.19	0.15	
Standard losses of Transformer							
No Load losses	16.8	17	KW	0.3	0.50	0.9	KW
Full(Cu) Load losses	68	68	KW	1.2	2.00	3.5	KW
Technical losses in Power Transformer in MU	0.149	0.21	MU	0.00	0.00	0.003	MU

Table 6
Analysis of Technical power losses after load bifurcation

After Load Bifurcation: Technical losses in Feeder Circuit						
11KV Feeder name	MONROE		ECR		LOCAL	
Lengh of Cable	9.46	KM	4.5	KM	7.08	KM
Peak Load	178.8	Amp	96	Amp	147.00	Amp
Average Load	120		80		125.80	
Load Factor	0.67		0.84		0.86	
Load loss Factor(0.20)	0.49		0.73		0.76	
Technical losses in Feeder	0.459	MU	0.09	MU	0.36	MU

Table 7
Voltage regulation in 11 KV Monroe feeders after load bifurcation

After Load Bifurcation: Voltage Regulation in Feeder Circuit							
SL.NO	11 KV CABLE	Distance in KM	Distribution Transformer	Capacity in KVA	Cumulative Load	Momentum	%Regulation
			BRANCH-1				
0	3x120	0.92	Chindadripet		4250	3910	1.01
1	3x120	0.82	NAVALAR RMU	250	4250	3485	0.90
2	3x120	0.78	NAPIER T;OFF	250	4000	3120	0.81
3	3x120	0.68	PALLAVAN	250	3750	2550	0.66
4	3x120	0.56	GYMKANA 4P	250	3500	1960	0.51
5	3x120	0.49	MONROE RMU	500	3250	1593	0.41
6	3x120	0.6	ISLAND RMU	250	2750	1650	0.43
7	3x120	0.42	PTC T'FF RMU	250	2500	1050	0.27
8	3x120	0.62	GARRISION	250	2250	1395	0.36
9	3x120	0.42	S.M.NR RMU	250	2000	840	0.22
10	3x120	0.57	GANDHI NR TP	250	1750	998	0.26
11	3x120	0.45	INDRA GI NR	250	1500	675	0.17
12	3x120	0.42	BAND	250	1250	525	0.14
13	3x120	0.6	SECRETRAIT	500	1000	600	0.16
14	3x120	0.51	CHURCH RMU	250	500	255	0.07
15	3x120	0.6	SECRETRAIT	250	250	150	0.39
	Total	9.46					6.75

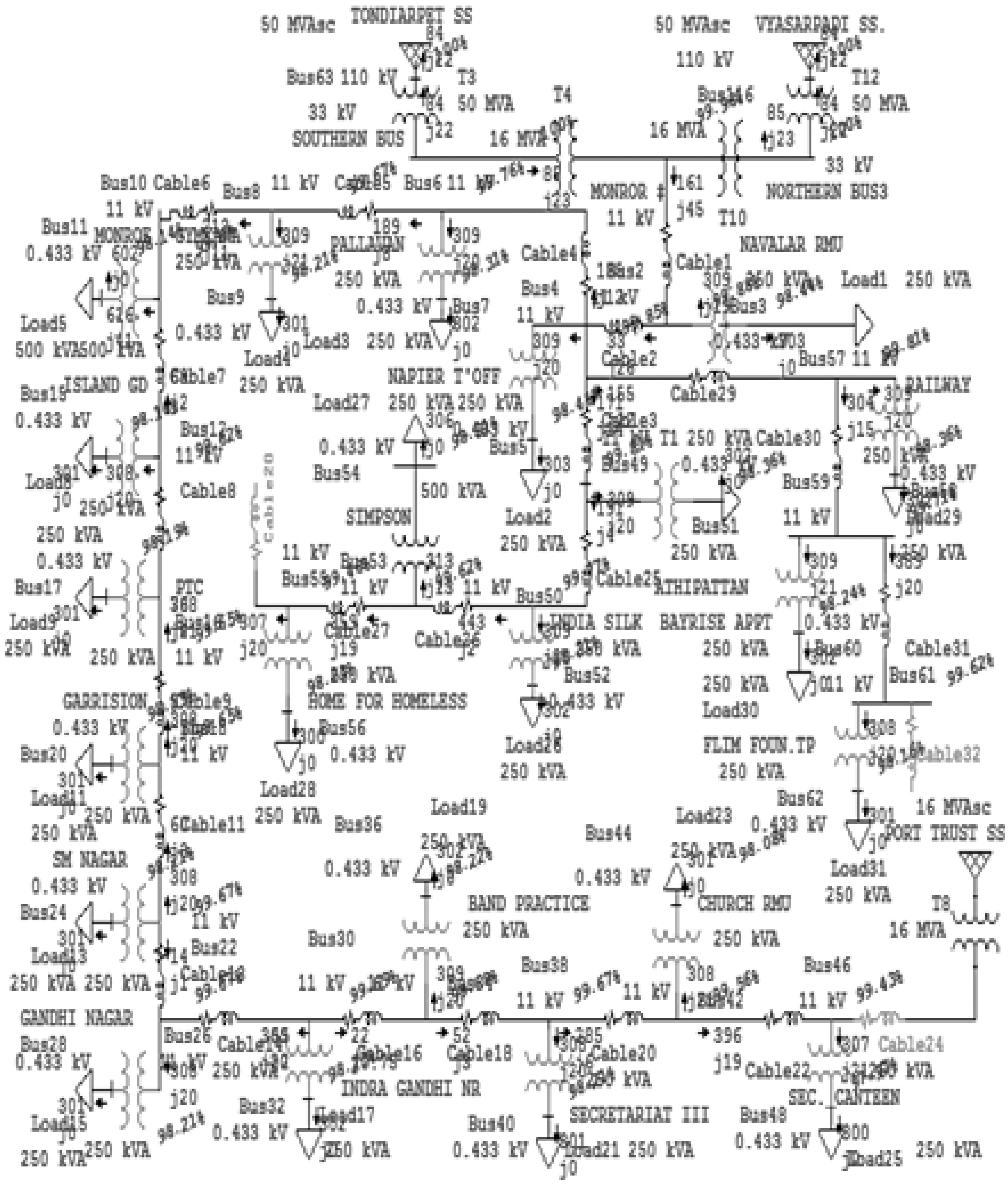

Figure 5: ETAP Simulation in power transformers (I&II), distribution transformers and 11 KV Monroe feeder circuits

Table 8
ETAP Simulation Voltage Drop in 11 KV Monroe feeder Circuits after load bifurcation

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7. RESULT

The case study has been successfully conducted and nett energy losses in 110 KV Chindadripet Sub-Station, over 0.346 Million Units is saved per annum after load bifurcation of 11KV Monroe feeder circuits. Also the % voltage regulations of 11 KV Monroe feeder circuit's is 10.57 to 6.75 values are achieved by before and after load bifurcation work carried out as shown in Table 9.

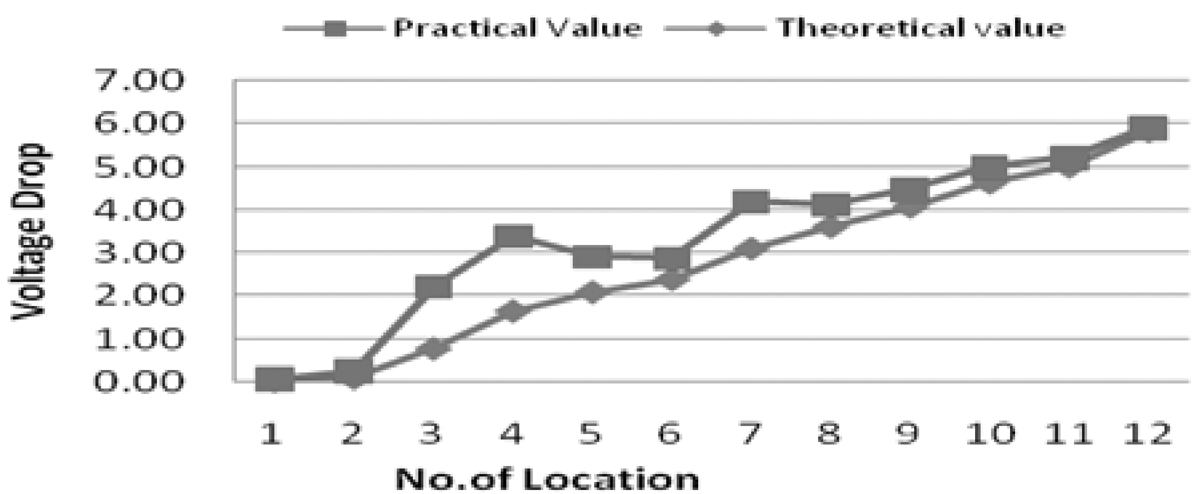

Figure 6: Comparison of Practical Vs Theoretical value voltage drop in 11 KV Monroe feeder

Table 9
Nett energy saving in whole power circuits before and after load bifurcation

Sl. No	Energy losses in power circuits	Before load bifurcation (MU)	After load bifurcation (MU)
1	Power Transformers	0.488	0.359
2	11KV feeders	1.054	0.909
3	Distribution Transformers	0.07	0.003
4	Total Energy losses	1.612	1.271
5	Voltage regulation	10.57	6.75
6	**Energy Saving per annum**	**0.341 MU**	

8. CONCLUSION

This paper highlights the analysis of Distribution losses and preventive measures in a Chennai Electricity Distribution Control Centre. The proposed measures include Load switching, Feeder re-configuration, Load reduction and voltage control. By proper selection of Power transformers, Distribution transformers and feeder circuits, Re-organization of distribution networks, Reducing length of LT lines, Bifurcation of HT lines, Fixing of compensating equipments at appropriate places and Training of operating personal would result in improved reliability and efficiency of the transmission and distribution system.

9. FUTURE WORK

The future work will be extended to solved by both On-load or off-load tap changing of power transformers at 230/110, 230/33, 110/33 and 33/11 voltage levels. For accurate calculation, energy meters could be connected at all distribution transformers and installing appropriate compensation equipments at vantage point of Sub-stations.

The loss reduction by connecting capacitors during peak period, were found to be 6-7% from simulation studies. By connecting the capacitors across all individual inductive loads, 10% voltage level improved, 20% reduction in current and reduced losses up to 9-13% can be achieved depending upon the extent of PF.

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