VOLTAGE REGULATION OF 11KV DISTRIBUTION FEEDERS –A CASE STUDY

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***ABSTRCT:** Voltage regulation describes the ability of a system to provide near constant voltage. Electric utilities aim to provide service to customers at a specific voltage level, for example, 220V or 240V. However, due to Kirchhoff's Laws, the voltage magnitude and thus the service voltage to customers will in fact vary along the length of a conductor such as a distribution feeder. Actual service voltage must be within a tolerance band such as ±5% or ±10% and this may be considered acceptable voltage over a wide range of load conditions. This paper presents a study of voltage regulation of two 11KV feeders and comparison is drawn between the values of practical voltage regulation and simulated voltage regulation. One among the feeders taken for study belong to the government owned Distribution Company and the other belongs to the co-operative society owned Distribution Company.*

***KEYWORDS:** Voltage regulation, Feeder, ETAP, ACSR, LLF*

I.INTRODUCTION

Most widely used distribution model is radial type which is very easy to realise and is of low cost but it suffers from poor voltage regulation and reliability. This type of network is less efficient as conductors carry large current at the substation and current magnitude continually reduces towards the end of the feeder as laterals and sub laterals are tapped off the feeder .As the current magnitude lessens the size of the conductor also reduces resulting in increased ohmic losses. Thus end users are supplied with less voltage than what is sent from utility.

Feeder voltage regulation refers to the management of voltages on a feeder with varying load conditions. Apart from nominal operating voltage, a utility distribution system is designed to deliver power to consumers within a predefined voltage range. Under normal conditions, the service and utilization voltages must remain within ANSI standard C84.1-2011 limits, defined as Range A. On a 120V base, this service range is defined as 114–126V and utilization range is 110-126V. During high load conditions, the source voltage at the substation is at the higher end of this range and the service voltages at the end of the feeder are at the lower end of the range. Thus, Voltage regulation is a measure of change in the voltage magnitude between the sending and receiving end of a component, such as a transmission or distribution line. Voltage regulation value for a particular feeder decides the efficiency of that feeder and hence, that distribution company in delivering near constant voltage at the service points of the consumer. This paper reveals a case study where in voltage regulation of two 11KV distribution feeders each belonging to different distribution companies is calculated with practical data. Further Practical results of voltage regulation are compared with simulated results of voltage regulation.

II.STUDY DESCRIPTION

This section involves the practical details of two 11KV feeders .One among the feeders is a government (HESCOM) owned IP feeder and the other is a co-operative society (HRECS) owned town feeder.

A. Practical results obtained at Co-operative society owned Facility:

SL No	From Node	To Node	Node KVA	Segment L in Km	Segment KVA	Volt Es	Volt Er	Node Current In A	Segment Current In A	P.P Loss In KW	%V.R
1	0	1	25	0.10	2427	11	10.990	0.88	85.06	1.30	0.09
2	1	2	100	0.10	2420	10.990	10.980	3.51	85.18	1.27	0.18
3	2	3	250	0.05	2302	10.980	10.975	8.77	81.68	0.58	0.23
4	3	4	100	0.05	2052	10.975	10.971	3.51	72.91	0.47	0.27
5	4	5	100	0.05	1952	10.971	10.967	3.51	69.40	0.420	0.30
6	5	6	100	0.05	1852	10.967	10.963	3.51	65.890	0.38	0.34
7	6	7	25	0.10	1752	10.963	10.955	0.88	62.38	0.68	0.41
8	7	8	25	0.10	1727	10.955	10.948	0.88	61.50	0.66	0.47
9	8	9	100	0.45	1702	10.948	10.916	3.53	60.62	0.90	0.76
10	9	10	25	0.10	1602	10.916	10.909	0.88	57.10	0.57	0.83
11	10	11	63	0.20	1577	10.909	10.896	2.23	56.21	1.11	0.95
12	11	12	25	0.20	1514	10.896	10.883	0.88	53.99	1.02	1.06
13	12	13	100	0.30	1489	10.883	10.864	3.54	53.10	1.48	1.23
14	13	14	100	0.20	1389	10.864	10.853	3.55	49.56	0.86	1.34
15	14	15	100	0.10	1289	10.853	10.847	3.55	45.01	0.37	1.39
16	15	16	63	0.20	1189	10.847	10.837	2.24	42.47	0.63	1.48

17	16	17	100	0.10	1126	10.837	10.832	3.55	40.23	0.28	1.53
18	17	18	25	0.10	1026	10.832	10.828	0.89	36.67	0.24	1.56
19	18	19	63	0.55	1001	10.828	10.804	2.24	35.79	1.23	1.78
20	19	20	63	0.20	938	10.804	10.799	2.25	33.54	0.39	1.85

Conductor Type: ACSR Rabbit Conductor Resistance = 0.584 Ω
RcosQ + XsinQ = 0.6886 D.F = 1.5

CALCULATION:
Total KVA load on the feeder = 1552 KVA.

- Length of the trunk line = 3.2 Km.
- Tail end voltage of the feeder, Er = 10.797 KV.
- %Voltage Regulation = $\frac{(Es - Er) \times 100}{Es} = \frac{(11 - 10.797) \times 100}{11} = 1.85$ %.

  Es=Sending end voltage; Er=Receiving end voltage
- Total peak power loss PPL = 16.84 KW (From Table.1)
- Annual Energy loss (AE loss) = PPL x LLF x 8760 = 16.84 x 0.408 x 8760
  = 60187.5072 units

  Where LLF(Loss at load factor of 0.4) =0.4
- Total A.E losses including spur line losses =AE loss + 10% of AE loss
  = 60187.5072 + 6018.75072.
  = 662206.25792 units.

B. Practical results obtained at government owned Facility:

SL No	From Node	To Node	Node KVA	Segment L in Km	Segment KVA	Volt Es	Volt Er	Node Current In A	Segment Current In A	P.P Loss In KW	%V.R
1	0	1	113	1.80	7255	11	10.132	4.29	369.33	727.01	7.89
2	1	2	63	0.10	7142	10.132	10.085	2.40	365.04	39.46	8.32
3	2	3	100	0.10	7079	10.085	10.037	3.83	362.63	38.94	8.75
4	3	4	100	0.05	6979	10.037	10.014	3.84	358.80	19.06	8.97
5	4	5	100	0.20	6879	10.014	9.920	3.88	354.95	74.61	9.81
6	5	6	100	0.24	6779	9.920	9.809	3.92	351.07	87.59	10.83
7	6	7	125	0.10	6679	9.809	9.763	4.93	347.15	35.68	11.25
8	7	8	25	0.14	6554	9.763	9.639	0.99	342.22	48.55	11.83
9	8	9	100	0.12	6529	9.639	9.644	3.99	341.23	41.37	12.32
10	9	10	63	0.12	6429	9.644	9.590	2.53	337.24	40.41	12.82
11	10	11	63	0.24	6336	9.590	9.432	2.56	334.71	79.61	13.80
12	11	12	63	0.20	6303	9.432	9.391	2.58	332.15	65.33	14.62
13	12	13	100	0.25	6240	9.391	9.278	4.15	329.57	80.40	15.65
14	13	14	163	0.12	6240	9.278	9.224	6.80	325.42	37.63	15.14
15	14	15	163	0.12	5977	9.224	9.172	6.84	318.62	36.07	15.62
16	15	16	100	0.20	5814	9.172	9.086	4.24	311.78	57.57	17.40
17	16	17	63	0.24	5714	9.086	8.983	2.70	307.54	67.21	18.34
18	17	18	163	0.20	5551	8.983	8.897	7.05	304.84	55.03	19.12
19	18	19	100	0.24	5488	8.897	8.796	4.38	297.79	63.02	20.03
20	19	20	125	0.52	5388	8.796	8.577	5.61	293.42	132.56	22.03

ConductorType: ACSR Weasel Resistance=0.987Ω RcosQ+XsinQ=1.0098
D.F =1.5

Tabulation:

- Total KVA load on the feeder = 1992 KVA.
- Length of the trunk line = 5.3 Km.
- Tail end voltage of the feeder Er = 8.408 KV.
- %Voltage Regulation = $\frac{(Es - Er) \times 100}{Es} = \frac{(11 - 8.408) \times 100}{11} = 23.5636$ %.
- Total peak power loss PPL = 1919.22 KW (From Table.8).
- Annual Energy loss (AE loss) = PPL x LLF x 8760 = 1919.22 x 0.408 x 8760
  = 6859445.818 units

  Where LLF = Loss at load factor of 0.4 = 0.408
- Total A.E losses including spur line losses = AE loss + 10% of AE loss
  = 6859445.818 +685944.5818
  = 7545390.4 units

III. Simulation and Analysis

The Simulations performed in this case study are carried out using ETAP 14.0 Demo version which limits the user to have only 12 AC buses in the one line diagram. Hence, the study here is confined only to three nodes of each of the feeders.

ETAP Tool:

ETAP® is the most comprehensive electrical engineering software platform for the design, simulation, operation, and automation of generation, transmission, distribution, and industrial systems. As a fully integrated model-driven enterprise solution, ETAP extends from modelling to operation to offer a Real-Time Power Management System. Network Analysis includes a powerful set of analytical tools that allow for simulation, prediction, design and planning of system behaviour utilizing an intelligent one-line diagram and the flexibility of a multi-dimensional database. Network Analysis includes Arc Flash, Short Circuit, Load Flow, Motor Acceleration, and Load Analyzer modules .This tool uses Adaptive Newton Raphson method for load flow analysis.

B. Simulation Analysis of 11 KV HRECS Town feeder using ETAP Power system software tool.

The load flow analysis of 11 KV town feeder operated by HRECS using ETAP tool up to node 3 is shown below.

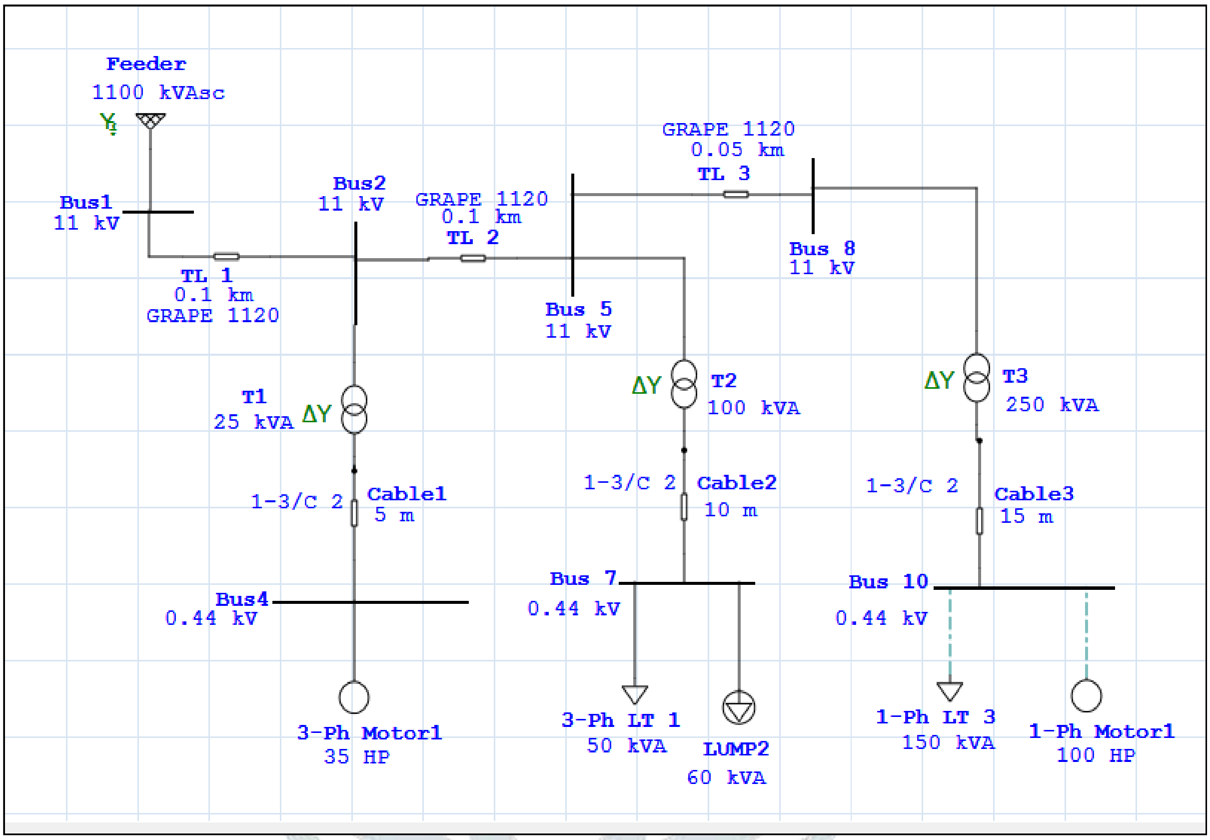


Figure.1 One line diagram of partial (up to node 3)11KV town Feeder of HRECS using ETAP

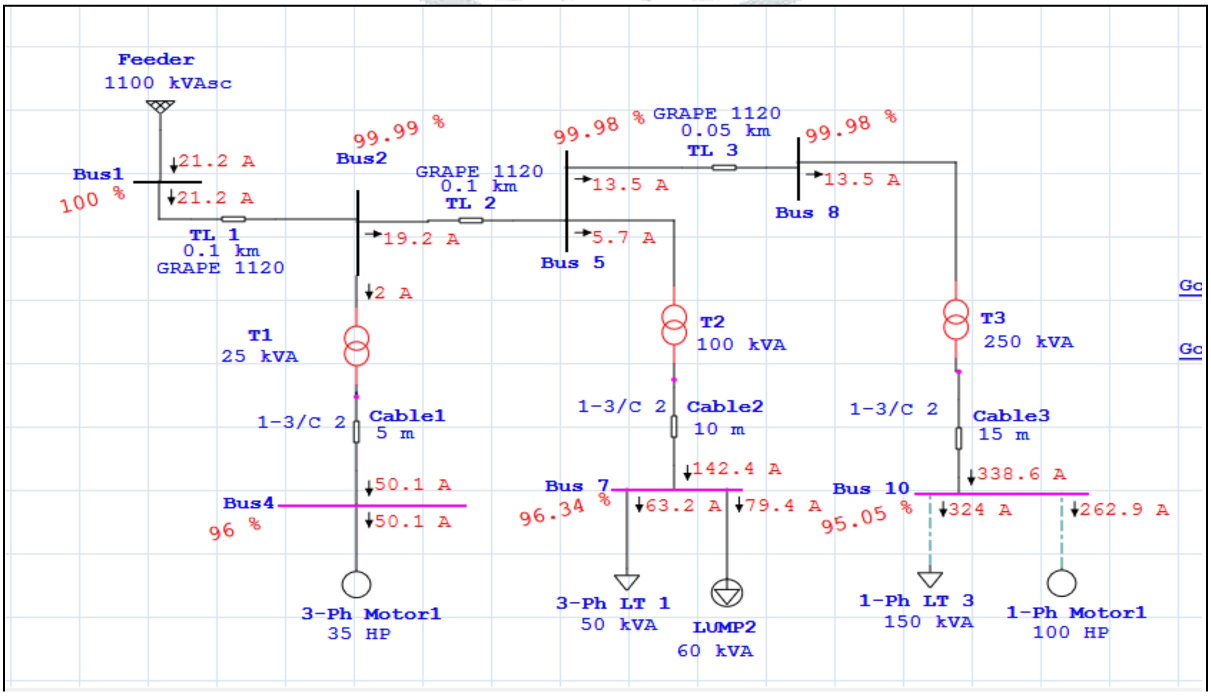


Figure.2 Load Flow Analysis of partial (up to node 3) 11KV town Feeder of HRECS using ETAP tool.

The description of components used in the ETAP simulation tool for Load flow analysis is show in the Table.1

Table.1 Equipment details used in one line diagram of HRECS town feeder.

Sl.No	Equipment Name	Rated Voltage KV	Description
1.	Feeder	11	Operation mode: swing
2.	Transmission Line	11	30 strand ACSR GRAPE-1120 Impedance per phase at 75'C Pos = 0.584, Neg = 0.584, Zero = 0.98 Length: TL1 = 0.1 Km, TL2 =0.1 Km, T L3 = 0.05 Km.
3.	Transformer	11/0.44	ANSI Liquid-fill 11/0.44 KV Step-down Distribution transformer T1: 25 KVA Δ/Y T2: 100 KVA Δ/Y T3: 250 KVA Δ/Y
4.	Service cable	0.6	50 Hz 0.6 KV ICEA-Rubber, Conductor: Al, 2 AWG/Kcmil Length: Cable1 = 5 m, Cable2 = 10 m, Cable3 = 5 m
5.	Induction Motor	0.44	Motor1: 3-Ph 6 Pole, 1200 rpm, 35 HP, 0.75 Pf induction motor Motor2: 1-Ph 6 Pole, 1200 rpm, 100 HP, 0.80 Pf induction motor
6.	Static load	0.44	LT1: 3-Ph 50 KVA LT3: 1-Ph 150 KVA
7.	Lump load	0.44	Lump2(60% motor 40% static) 60 VA, 0.85 pf

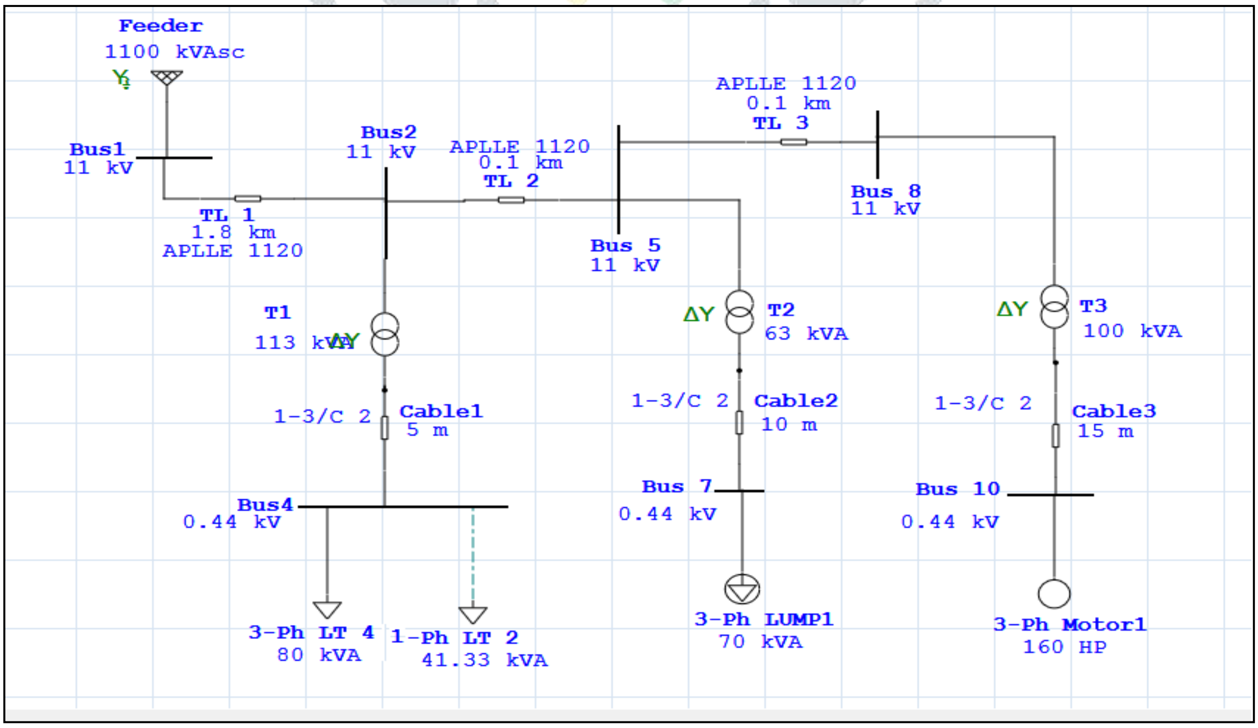
Simulation result:

- Total KVA load on the feeder = 406.65 KVA.
- Length of the trunk line = 0.25 Km.
- Tail end voltage of the feeder Er = 95.05% of 440 V = 418.22 V.
- $$\%\text{Voltage Regulation} = \frac{(Es - Er) \times 100}{Es} = \frac{(440 - 418.22) \times 100}{440} = 4.95\ \%.$$
- Practical %VR up to node 3 = 0.23%
- Error in Er= 438.98 - 418.22 = 20.76 V.
- 4.729 %Error in obtaining Er as per practical case.

C. Simulation Analysis of 11KV Government Owned IP Feeder using ETAP Power system software tool:

The load flow analysis of 11 KV IP feeder operated by HESCOM using ETAP tool up to node 3 is as shown in Figure.3

Figure 3. One line diagram of partial (up to node 3) 11 KV HESCOM IP Feeder using ETAP tool.



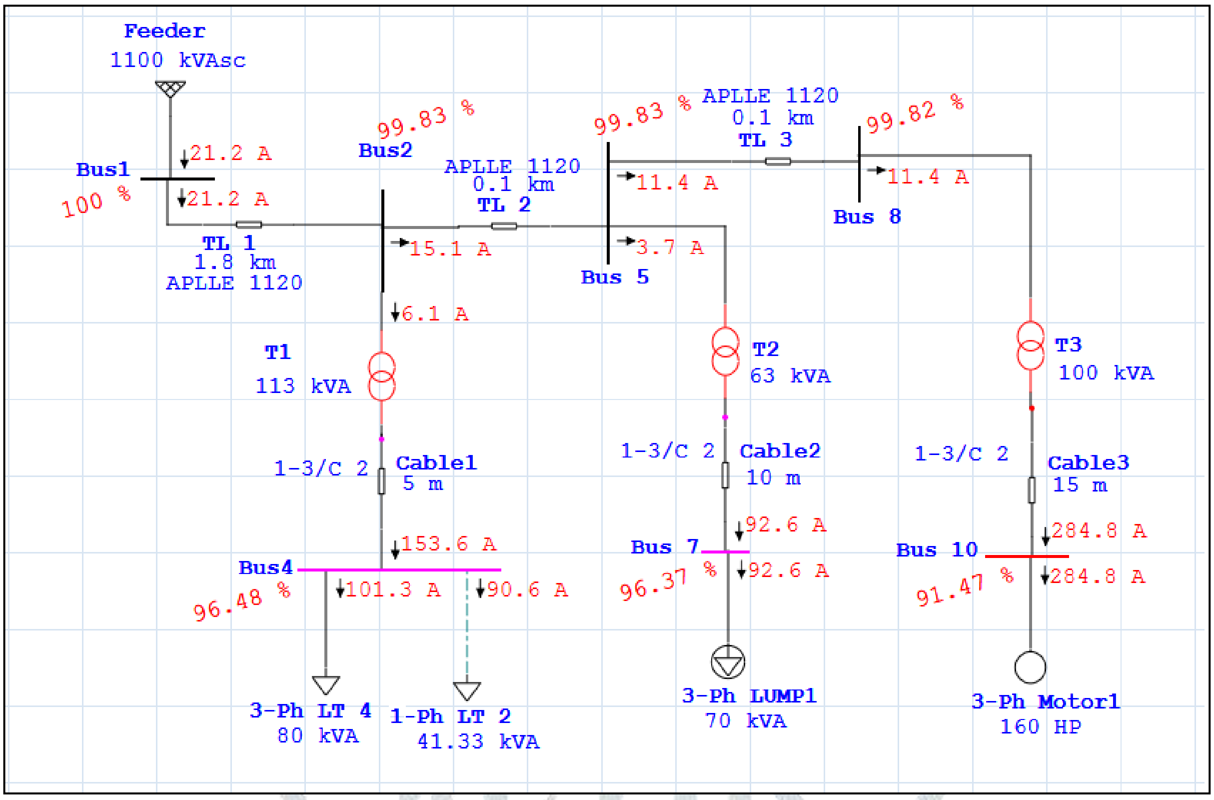


Fig 4. Load Flow Analysis of partial (up to node 3)11KV HESCOM IP Feeder using ETAP tool.

The description of components used in the ETAP simulation tool for Load flow analysis is show in the Table2.

Table 2. Equipment details used in one line diagram of HESCOM IP feeder

Sl.No	**Equipment Name**	**Rated Voltage KV**	**Description**
1.	Feeder	11	Operation mode: swing
2.	Transmission Line	11	6 strand ACSR APLLE-1120 Impedance per phase at 75’C Pos = 0.91, Neg = 0.91, Zero = 1.058 Length: TL1 = 1.8 Km, TL2 =0.1 Km, T L3 = 0.1 Km.
3.	Transformer	11/0.44	ANSI Liquid-fill 11/0.44 KV Step-down Distribution transformer T1: 113 KVA Δ/Y T2: 63 KVA Δ/Y T3: 100 KVA Δ/Y
4.	Service cable	0.6	50 Hz 0.6 KV ICEA-Rubber, Conductor: Al, 2 AWG/Kcmil Length: Cable1 = 5 m, Cable2 = 10 m, Cable3 = 5 m
5.	Induction Motor	0.44	Motor1: 1-Ph 4 Pole, 1800 rpm, 160 HP, 0.85 Pf induction motor
6.	Static load	0.44	LT4: 3-Ph 80 KVA LT2: 1-Ph
7.	Lump load	0.44	Lump2(60% motor 40% static) 70 KVA, 0.85 pf 41.33 KVA

V. Conclusion:

The comparative study of two feeders revealed that a cooperative society owned Distribution Company is efficient enough whereas a government owned feeder is not that efficient in meeting the requirements of consumers. That is voltage regulation of the former feeder is in satisfactory as per standards than the latter feeder. Every distribution company must aim at keeping the LT (Low tension) lines and HT (High

Tension) lines ratio to be constant. That is every new installation must be provided with extended HT line instead of supplying with LT line. If the LT line segment equals the HT line segment then distribution network will achieve near to 100% efficiency with no considerable losses in it. It is because distribution of power at high voltage causes less voltage drops hence less voltage regulation. Thus consumers are supplied with same voltage as that is sent from utility. Ring type distribution network is another alternative. In this type the size of the feeder conductor is kept the same throughout the loop (ring).It is selected to carry its normal load plus the load of the other half of the loop hence current carried by the conductor is less, so ohmic losses are small. This provides high service reliability and good voltage regulation.

VI. References

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[3] American National Standard For Electric Power Systems and Equipment— Voltage Ratings (60 Hertz) © Copyright 2011 by National Electrical Manufacturers Association.