RURAL ELECTRIFICATION

A Thesis Submitted to

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of

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by

Ingwald H. Gronseth

Candidate for the degree of

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CONTENTS

Foreword

Electrification of rural and farm communities has taken a stride ahead during the past few years, this advancement being due, primarily, to the rapid advancement made by the central station companies in the reduction of the cost of electricity and the now almost total electrification of urban territories, which has made it necessary that new fields be developed. Then too, the farmer has seen his city neighbor become prosperous and relieved from many of the backbreaking drudgeries through the use of electric light and power and it is only natural that he should become envious and desire these things for himself.

Need for careful study of this problem of electrifying the farm is apparent. The central station companies can not rush blindly in without giving proper consideration to all its phases. Not only must they guarantee to give a service which is above criticism but they must also be given a return for this service that is fair to both them and the consumer. This calls for rates that are different than those used in populous places, and the factors affecting these rates are the principal features the writer has had in mind in preparing this thesis.

A work as short as this can only touch the surface. Time and indefatigable study by all concerned will be necessary for a satisfactory solution. It is hoped, however, that what has been here presented will be of some value to those who are interested in this problem.

The Board of Water and Electric Light Commissioners of the City of Lansing and Mr. J.K. Pettingill, Chief Engineer of the Michigan Public Utilities Commission have been of great assistance in assembling the data used, and criticisms of Professors J. J. Gallagher and A. Baeter, Michigan State College have been of inestimable value.

Ingwald H. Gronseth

GENERAL CONSIDERATIONS

Relation of Agriculture to Industry

The farmers of to-day occupy a more important place than ever before in the history of the United States. With the ever increasing industrial expansion and the consequent grouping of population into large centers we become more and more dependent upon the farmer for our existance. Agriculture is our primary industry, we are dependent upon the products of the soil for our necessities of life, this dependence increasing with growth of population and the use of land for other purposes.

The great post-war industrial activity with its inflation of labor costs caused a great exodus of the rural population to the industrial centers, leaving a large portion of our farms short of labor for tilling and harvesting. The prices offered for farm produce had not kept pace with the prices offered for labor by other industries, taxes as well as the cost of farm implements rose steadily, and the farmers found themselves working for just a bare living and without the wherewithall to buy those comforts that the people of the more populous centers could get at a reasonable cost.

The condition of the farmer at the present time is steadily improving, his purchasing power is increasing accordingly and it is only natural that he should be clamoring for those luxuries and necessities of life which he formerly had been unable to obtain or which he had previously thought of as something he could very well get along without. A Great many of those who had left the farm, finding that the conditions are improving, are willing and anxious to return but they are reluctant to leave the conveniences of the city home to which they have become accustomed.

The one thing above any other that the urbanite has become used to and which has lessened his work more than any other is electricity. He has seen how this great benefaction has been used to improve his lot, has seen his wife relieved of a large portion of those drudgeries of the home, giving her more leisure, more time for enjoyment and recreation, and more time for the enjoyment of the home itself. The farmer who did not desert his place has seen these things too, and having more confidence in the future and more purchasing power he has begun to think seriously of obtaining these conveniences for himself. The cooperation of Central Station Companies has been obtained and committees have been organized to study the problem of electrifying the farm. Many of our institutions of higher learning are taking an important part in these studies and endeavoring to educate the farmer in the uses of electricity.

The Central Station Companies realize the interdependence of rural and industrial life and have joined in the move, not only because of possible increase in their own revenues but also through a sincere desire to be of help, not loosing track of the fact, however, that the factor of revenue is all important.

Field of Application

The field of application of electricity on the farm is well nigh unlimited. Lighting of the home and outbuildings, of course, is the most important, but there are many other uses to which electricity can be placed and from which the farmer can derive real profits. The advantages of electric cooking and refrigeration are well known and no housewife who has used the electric washing machine and iron will want to give them up. The dependence upon wind or elbow greasefor the pumping of water is done away with by the use of an electric motor which can be started by the simple operation of pressing a button or throwing a switch and which can be made to make the water flow to any point where it is required through the necessary piping and faucets. The heating of water may be done with an electric heater at a reasonable cost. No longer is it necessary for the farmer to haul his feed to the mill to have it ground, portable or stationary electric motors can be attached to his own grinder and a saving in time and money accomplished. Milking machines is as necessary an adjunct to the dairy farm as electric brooders to the hennery. The filling of silo, hayloft and granary may be done by electricity, and the farm shop made really utilitarian. The growth of plants may be expedited and the egg yield increased considerable by the use of electricity. The harvesting of crops and threshing of grain can be done with a saving of time and labor and experiments on plowing with the aid of electricity have been carried on by one of the leading Agricultural Colleges.

Service

The quality of service given rural customers must be of the best. Load density, of course, is the deciding factor of who shall be served first in case of general outages, but rural lines must **not be** killed upon just any sort of pretext, just because it may be thought that the load is light and unimportant. It may not be unimportant to the farmer. He may be dependent upon this service for his water, the milking of his cows, hatching of his chicks and other uses, the curtailment of which may mean a serious loss. He will be paying for the best service that the service companies can give and it should be given without descrimination.

Future Demand

The future demand will depend largely upon the quality of service given. The more the farmer feels that he can depend on his electric service the more tasks he will give it to perform. It is problematical what the rate of increase will be and what the point of saturation is as other factors enter into this besides that of quality of service. However, it is reasonable to expect that the demand during the second year will exceed that of the first by 25% and that the consumption should reach at least 200 kwh per month.

Education

The education of the farmer in the uses of electricity will be the controlling factor of ultimate consumption. He must be shown how and when it can be used

to the best advantage, must be advised in the selection of proper equipment and apparatus and must be given service on such equipment and apparatus after it has been installed. Many an electric range has been discarded because of excessive bills caused by ignorance on the part of the housewife in the proper use of it and making her a knocker instead of a booster for this excellent load builder. Oftentimes too, the farmer will be unable to pay cash for the equipment that he needs and it will be necessary for the central station companies to help in arranging a suitable method of time payment.

CONSTRUCTION OF LINES

Location of Lines

As farmsteads are usually located along established roads no difficulties will be encountered that will tend to make the cost of the line abnormal. Where high tension lines have been built along the road it may be necessary, in order to obtain proper clearances, to locate the line on the opposite side of the road from such high tension line unless communication lines will interfere with such location. Interference from trees should be avoided in order to reduce possibilities of outages. In many cases it may be advisable to obtain private right of way preferably just inside the property lines in order to eliminate interference. This can usually be obtained at no cost as the farmers along the road for whom the line is being constructed

will be more than glad to grant easement without charge in order to get the service.

Types of Construction

The best type of construction consistent with good service is usually the most economical. Depreciation and maintenance are the two major factors to be considered, as a line constructed of inferior materials and workmanship will greatly increase the maintenance cost and decrease the life of usefulness of the line. The line voltage, of course, is of major influence in determining the type of construction to be used, but for most rural lines, a line voltage of 4000 or 6600 will be sufficient to handle the load and give sufficient regulation. A voltage of 4000 has been used in the calculations in this problem.

The height and class of poles to be used will depend on the nature of the country and obstructions by other lines, trees, etc., and the span length to be used. For most rural lines 30 ft class B or C poles will be satisfactory and will allow proper clearances for span lengths up to 200 ft using #6 bare, stranded copper wire. Butt-treatment of poles will increase their life approximately 75% and the cost of such treatment will be more than offset by the decrease in depreciatio and maintenance.

Some of the larger central station companies are using aluminum wire for rural distribution in order to decrease the initial investment of the line. By the use of aluminum wire span lengths of 300 ft or more may be used thereby reducing the number of poles and other materials, and affecting a saving in labor costs. Copper wire, however, will probably continue to remain the standard with most companies and this wire has therefore been used in this problem.

The difference in cost between four (4) and six (6) ft. cross-arms is very small and does not materially affect the cost of the line as a whole and either size may be used for single-phase or three-phase lines. Pole line hardware should be of the best quality and will not vary for any type of construction except in quantity.

In many cases agreements may be made with telephone companies for joint construction and use of rural lines. This will decrease the investment of both companies and will make very little difference in the maintenance costs. Poles of 35 ft in height will generally be suitable for this type of construction.

Material and Labor Costs

On pages 10 to 14 inclusive material and labor costs have been itemized for both single and joint construction and for three different span lengths. The cost of materials will not vary appreciably throughout the Central States. For labor costs, the writer has drawn upon his experience in estimating and superivsion as well as actual constriction, experience, and has combined this with published data taken from periodicals and text-books.

Construction Material and Costs

Per Mile of Line

Description	126' Span		151' Span		176' Span	
	No.	Cost	No.	Cost	No.	Cost
Poles, 30 ft. Butt treated	42	420.00	35	350.00	30	300.00
Crossarms, 6 ft.	46	32.20	39	27.30	34	23.80
Pins, steel	92	15.64	78	13.26	68	11.56
Insulators, Porc.	92	12.42	78	10.53	68	9.18
Carriage bolts	92	1.84	78	1.56	68	1.36
Crossarm braces	92	12.42	78	10.53	68	9.15
Lag screws	46	1.20	39	1.01	34	.68
Through bolts	44	3.52	37	2.96	32	2.56
Space bolts	4	.48	4	.48	4	.48
Anchors, screw	4	10.24	4	10.24	4	10.24
Strain Insulators	4	.56	4	.56	4	.56
3-bolt clamps	8	3.20	8	3.20	8	3.20
Strain plates	8	.80	8	.80	8	.80
Guy hooks	8	.32	8	.32	8	.32
Guy strand, 5/16	200'	4.00	200'	4.00	200'	4.00
Miscellaneous 10%		51.68		43.67		37.81
TOTALS		$570.72		$480.42		$415.90

No. 6 Weatherproof copper wire @ $.177/# ---------- $219.80

No. 6 Bare copper wire @ $.171/# ---------------- $150.82

Construction Materials and Costs

Per Mile of Line

(Joint Construction)

Description	126' Span No.	126' Span	151' Span No.	151' Span	176' Span No.	176' Span
Poles 35 ft But treated	42	306.81	35	255.68	30	219.15
Crossarms	46	32.20	39	27.30	34	23.80
Pins, steel	92	15.64	78	13.26	68	11.56
Insulators, Porc.	92	12.42	78	10.53	68	9.18
Carriage bolts	92	1.84	78	1.56	68	1.36
Crossarm braces	92	12.42	78	10.53	68	9.18
Lag screws	46	1.20	39	1.01	34	.88
Through bolts	44	3.52	37	2.966	32	2.56
Space bolts	4	.48	4	.48	4	.48
Anchors, screw	2	5.12	2	5.12	2	5.12
Strain Insulators	2	.28	2	.28	2	.28
3-Bolt clamps	4	1.60	4	1.60	4	1.60
Strain plates	4	.40	4	.40	4	.40
Guy Hooks	4	.16	4	.16	4	.16
Guy strand, 5/16"	100'	2.00	100'	2.00	100'	2.00
Miscellaneous 10%		39.61		33.29		25.77
TOTALS		$435.70		$366.16		$283.48

Labor Costs

Per Mile of Line

Description	126' Span Cost	151' Span Cost	176' Span Cost
Digging holes, clay dirt 8 ft. deep	105.00	87.50	75.00
Setting poles	126.00	105.00	90.00
Instal. anchors & Guys	20.00	20.00	20.00
Installing crossarms, Pins and Insulators	34.50	26.25	22.50
Stringing wire	158.40	158.40	158.40
Hauling material	75.00	70.00	65.00
Misc.Labor(Trimming etc)	30.00	30.00	30.00
Superv. & Engineering10%	54.89	49.72	46.09
TOTALS	$603.79	$546.87	$506.99

Labor Costs

Per Mile of Line

(Joint Construction)

For cost of joint construction, one-half the cost of digging holes and setting poles, guying, tree trimming, and haulage should be deducted from the above totals plus the supervision and engineering charge on the amount deducted, as this amount will be charged to the joint occupant.

NEW TOTALS	$407.99	$374.99	$352.99

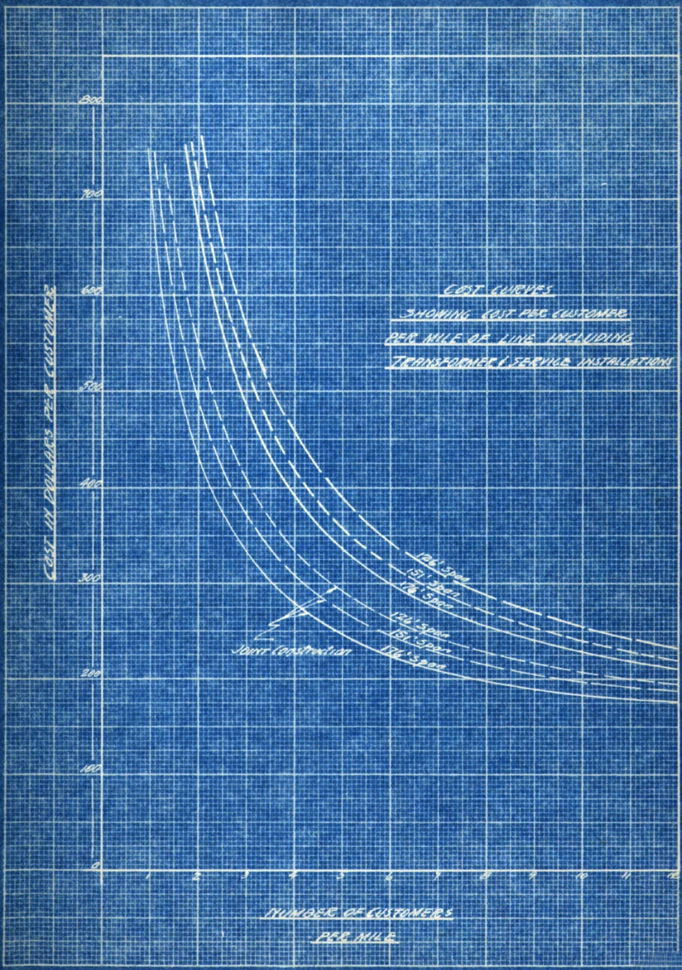
Line Cost per Customer

No. of Customers per mile	Line material cost	Line labor cost	Transf. instal. cost	Service instal. cost	Total
126 ft. Spans					
4	180.38	150.95	94.38	28.22	453.93
5	144.31	120.78	94.38	28.22	387.75
6	120.26	100.63	94.38	28.22	343.49
7	103.08	86.25	94.38	28.22	311.93
8	90.19	75.46	94.38	28.22	288.25
9	80.17	67.09	94.38	28.22	269.86
10	72.15	60.38	94.38	28.22	255.13
151 ft. Spans					
4	157.81	136.72	94.38	28.22	417.13
5	126.24	109.37	94.38	28.22	358.11
6	105.20	91.14	94.38	28.22	318.94
7	90.17	78.12	94.38	28.22	290.89
8	78.90	68.36	94.38	28.22	269.86
9	70.13	60.75	94.38	28.22	253.48
10	63.12	54.69	94.38	28.22	240.41
176 ft. Spams					
4	141.68	126.75	94.38	28.22	391.03
5	113.35	101.40	94.38	28.22	337.35
6	94.45	84.50	94.38	28.22	301.55
7	80.96	72.42	94.38	28.22	275.98
8	70.84	63.37	94.38	28.22	256.81
9	62.97	56.33	94.38	28.22	241.90
10	56.67	50.70	94.38	28.22	229.97

Line Cost Per Customer

(Joint Construction)

No. of Customers per mile	Line material cost	Line labor cost	Transf. instal. cost	Service instal. cost	Total
126 ft. Span					
4	108.92	101.99	94.38	28.22	333.51
5	87.14	81.59	94.38	28.22	291.33
6	72.61	67.99	94.38	28.22	263.20
7	62.24	58.28	94.38	28.22	243.12
8	54.46	50.99	94.38	28.22	228.05
9	48.41	45.33	94.38	28.22	216.34
10	43.57	40.79	94.38	28.22	206.96
151 ft. Span					
4	91.54	93.73	94.38	28.22	307.88
5	73.23	74.99	94.38	28.22	270.72
6	61.02	62.49	94.38	28.22	246.11
7	52.30	53.57	94.38	28.22	228.47
8	45.77	46.87	94.38	28.22	215.09
9	40.68	41.66	94.38	28.22	204.94
10	36.61	37.49	94.38	28.22	196.70
176 ft. Span					
4	65.87	88.24	94.38	28.22	276.71
5	52.69	70.59	94.38	28.22	245.88
6	43.91	58.83	94.38	28.22	225.34
7	37.64	50.42	94.38	28.22	210.66
8	32.93	44.12	94.38	28.22	199.65
9	29.27	39.22	94.38	28.22	192.09
10	26.34	35.29	94.38	28.22	184.23



COST CURVES
SHOWING COST PER CUSTOMER
PER MILE OF LINE INCLUDING
TRANSFORMER & SERVICE INSTALLATIONS
COST IN DOLLARS PER CUSTOMER
NUMBER OF CUSTOMERS
PER MILE
126' Span
151' Span
176' Span
126' Span
151' Span
176' Span
Joint Construction
0
100
200
300
400
500
600
700
800
1
2
3
4
5
6
7
8
9
10
11
12

Transformer Installations

Due to the distances separating rural customers it will be found necessary, in the majority of cases, to install a separate transformer for each. The size to be used will depend on the maximum load that the transformer will be called upon to carry and for this type of customer this load may be quite large. From data published in C.R.E.A. Bulletin Vol. 4, No. 1, the average connected load in 5 states was 14.2 Kw. with an average monthly energy consumption of 264.5 Kwh. Ordinarily, ranges and water heaters will cause the greatest demand and as these two pieces of equipment may very often be in use at the same time the maximum demand may reach 5 or 6 Kw. The transformer will have to be sufficiently large to take care of this load without excessive voltage drop as experience has shown that ranges will not operate satisfactorily unless the regulation is very close. Though transformers will stand overloads of 300% or more for short periods of time it does the transformer no good, nor does it give the customer as good service as he should have.

Another influence in the size of transformers to be used is the amount of stock carried by the utility. Transformers below 3 Kw in size are a rarity on most systems and few will be found even on rural lines.

Page 17 shows that the total transformer capacity on the lines studied and which covered 50 customers amounted to 101.5 Kva, giving an average Kva installed per customer of 2. approximately.

The cost of transformer mountings and auxilliary equipment on rural lines will be approximately the same for all transformer sizes. Fuse cut-outs, lightning arrestors and crossarms, pins and insulators will have to be used on all, the only difference in cost being caused by the cost of the transformer itself. Page 18 shows an itemized list of material used on a typical transformer installation with material and labor costs.

Where the customers are close enough together it may be advisable to connect two or more customers on to the same transformer. In order to determine which will be the best, whether to install secondaries or individual transformer, it will be necessary to compare the cost of the secondary installation plus its line losses and increased transformer size and transformer losses against the individual installation.

Service Installation

The service installation cost will remain practically constant for all installations. By service is meant the necessary wire from the nearest pole to the house, equipment for attaching to house and pole and a three-wire, 25 amp. meter. The material, cost of same, and installation labor costs are shown on page 18.

TRANSFORMERS INSTALLED

1½ Kva		3 Kva		5 Kva	
No. of Customers	No. of Transf.	No. of Customers	No. of Transf.	No. of Customers	No. of Transf.
3	3	6	6	3	3
		24	12	8	4
		3	1	3	1

Total Kva in transformer capacity installed -------- 101.5

Average Kva per customer -------------------------- 2.

Total number of transformer installations ---------- 30

Number of transformers installed per customer ------ .6

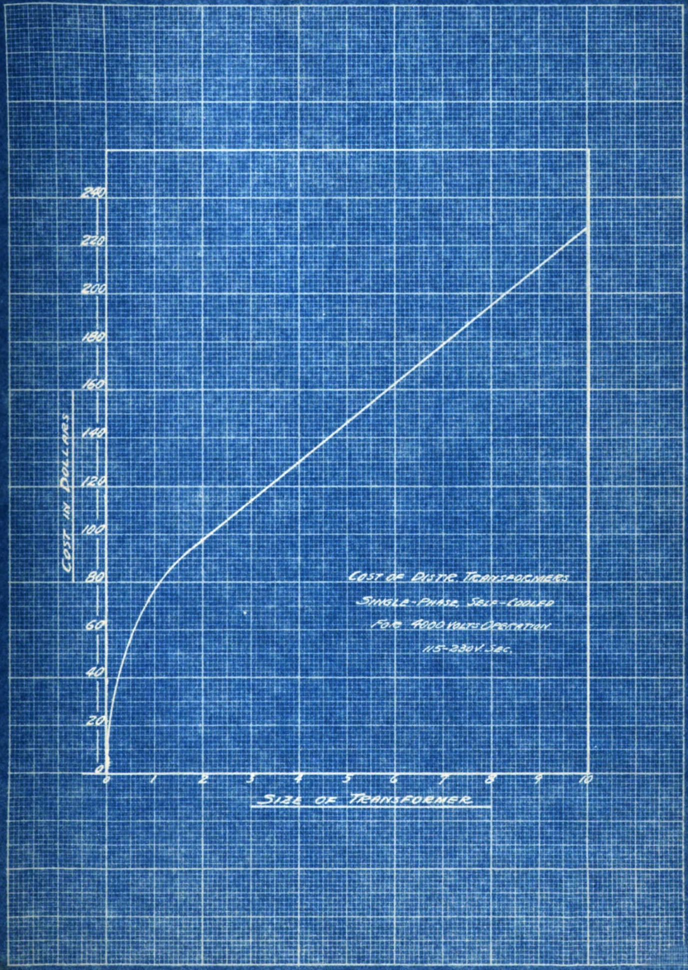
Transformer Installation Cost

Transformer, 2 Kva, 4000/115-230, ------	$45.40	
Lightning arrestors, 5000 volts, -------	10.20	
Cut-outs, ------------------------------	12.00	
Ground rods, --------------------------	2.00	
Wood moulding, ------------------------	.75	
Cross-arms, --------------------------	1.00	
Pins and insulators, ------------------	1.22	
Miscellaneous hardware, ---------------	.60	
Wire, ---------------------------------	1.00	
Handling charge, 5% -------------------	3.71	$77.88
Labor cost of transf. inst. ------------	$15.00	
Supervision & engineering 10% ----------	1.50	$16.50
Total cost of installation -------------		$94.38

Cost of Service Lines

(Lenght of service, 100 ft.)

Meter, 3 wire, 110-220 volt, -----------	$13.10	
Wire, W.P., #6, copper, ----------------	5.77	
Brackets, ------------------------------	1.20	
Handling charge, 5% --------------------	1.00	$21.07
Labor cost of Meter Inst., -------------	1.50	
Labor cost of service inst., -----------	5.00	
Supervision & Engineering 10%, ---------	.65	7.15
Total cost of service installation -----		$28.22


COST OF DISTR. TRANSFORMERS
SINGLE-PHASE, SELF-COOLED
FOR 4000 VOLTS OPERATION
115-230 V. SEC.
COST IN DOLLARS
0
20
40
60
80
100
120
140
160
180
200
220
240
0
1
2
3
4
5
6
7
8
9
10
SIZE OF TRANSFORMER

CONSUMPTION AND DEMAND

The data shown on pages 20 to 22 inclusive is probably typical in that it is taken from a territory where there has been no organized effort on the part of the central station company in the education of the farmer in the proper uses of electricity. The farms vary in size from 40 acres to 320 acres, and are fairly prosperous. Though the growing of grain predominates, several are given over to dairying and truck gardening. Several have electric pumping equipment, about 20% are equipped with ranges practically all have washers and other small household appliances.

For purposes of comparison the average monthly consumption of 26 farms was taken for the year of 1927 and 50 farms for the year of 1928. The average monthly consumption for 1927 was found to be 61 Kwh while for 1928 the average monthly consumption was 76 Kwh, giving an increase over 1927 of 15 Kwh per month of 24.6%.

Pages 20 to 22 inclusive show in a tabulated form the average monthly consumptions. The data in the columns 1927 and 1928 does not pertain to the same customer as might be inferred. The customer number is used merely for totalizing purposes. The data as a whole compares very favorably with the data given Progress Report No. 2 of the Michigan Engineering Experiment Station and which shows an average monthly consumption of 58.6 Kwh per customer on the Mason - Dansville experimental line.

Customer	Average monthly consumption in Kwh	
	1927	1928
1	31	55.2
2	12	18.2
3	36	58.3
4	40	38.5
5	65	95.5
6	50	82.5
7	35	27.9
8	39	76.3
9	314	162.
10	11	12.
11	35	55.3
12	16	23.7
13	28	58.1
14	30	46.1
15	15.5	26.2
16	25	62.5
17	37	34.7
18	9	27.8
19	20	52.8
20	57	95.
21	21	24.4
22	12	16.7
23	61	60.5
	999.5	1210.2

Customer	Average monthly consumption in KWH	
	1927	1928
Carried forward	999.5	1210.2
24	560.	308.
25	22.	34.9
26	26.	36.5
27		205.
28		35.2
29		141.
30		51.7
31		56.3
32		44.2
33		21.7
34		151.5
35		34.2
36		42.
37		37.5
38		72.6
39		69.
40		47.
41		186.
42		24.3
43		74.9
44		64.6
	1607.5	2948.5

Customer	Average monthly consumption in KWH	
	1927	1928
Carried Forward	1607.5	2948.5
45		11.3
46		69.7
47		26.5
48		177.
49		525.
50		45.1
Totals	1607.5	3803.1

Average Monthly KWH 1927 ------ = 1607.5/26 = 61.06

Average Monthly KWH 1928 ------ = 3803.1/50 = 76.06

KWH increase over 1927 --------------------- = 15.

KWH increase over 1927 in percent ----------- = 24.6

LOSSES

In order to compute the losses the number of hours use of the demand has been taken as 5.5 hours, giving a no-load period of 18.5 hours. The average demand per customer is found by dividing the average monthly consumption of page 22 the number of days in the month and by the number of hours use. The power factor of the load has been assumed as 90% and the meter loss as 1.85 watts per customer.

In computing the line losses the resistance of generators and equipment such as step-up or step-down transformers has been neglected due to difficulty in assuming a representative value. The line has been assumed to consist of No. 6 AWG copper wire, six (6) miles long from the feed point to the farthermost customer and having a resistance of 2.13 ohms per mile. The load has been considered to consist of five (5) customers per mile and to be grouped at the end of each mile. The load and no-load currents used in computing line losses are shown on page 24.

Assumed number of hours use of demand ---------------- 5.5

Number of hours of no-load --------------------------- 18.5

Average demand per customer = 76060/(30.4 x 5.5) = 455 watts

- -

Meter losses per customer -------------------------- 1.85 watts

- -

Transformer losses

Iron loss -- 30 watts

Copper loss at full load --------------------------- 52 watts

Efficiency of transformer at 1/4 load -------------- 93.8 %

Transformer loss at 1/4 load = (500-500 x .938)/.938 = 33 watts

Copper loss at 1/4 load = 33 - 30 ------------------ 3 watts

- -

Load current

Total load on transformer = 455 + 33 + 1.85 = 489.85 watts

Assumed power factor of load ----------------------- 90%

Load line current = 490.3/(4000 x .9) -------------- = .1361 amps

- -

No-load current

No-load losses = 30 + 1.85 ------------------------- = 31.85 watts

No-load power factor = Iron loss of transformer / 1000 (Exiting current / F.L. current) x Kva of transf.

= 30/(1000 x .04 x 2) = .375

No-load current = 31.85/(4000 x .375) ------------- = .0212

Load Line Losses

Mile	Total Customer	Current per customer	Total current	$(Current)^2$	Losses
First	30	.1361	4.083	16.67	35.5
Second	25	.1361	3.4	11.56	24.6
Third	20	.1361	2.722	6.41	13.65
Fourth	15	.1361	2.041	4.16	8.86
Fifth	10	.1361	1.361	1.85	3.94
Sixth	5	.1361	.68	.462	.99

Total -- 87.54

Average load line loss per customer -------------------- 2.92 watts

No-Load Line Losses

Mile	Total Customer	Current per customer	Total current	$(Current)^2$	Losses
First	30	.0212	.636	.404	.86
Second	25	.0212	.53	.281	.597
Third	20	.0212	.424	.18	.38
Fourth	15	.0212	.318	.101	.215
Fifth	10	.0212	.212	.045	.096
Sixth	5	.0212	.106	.0112	.024

Total -- 2.172

Load line loss per month = 2.92 x 5.5 x 30.4 --- = 488.22 watts

" " " " year = .488 x 12 ---------- = 5.86 Kwh

- -

No-load line loss per month = .072 x 18.5 x 30.4 = 40.5 watts

" " " " " year = .0405 x 12 ------- = .486 Kwh

- -

Total monthly line losses per customer = 488.22 + 40.5 = .529 Kwh

" yearly " " " " = ------------- = 6.35 Kwh

Summation of Losses

Meter loss -------------- = 1.85 x 8760 -------------- =16.2 Kwh

Transf. iron loss ------- = 30 x 8760 ---------------- =262.8 Kwh

Transf. copper loss ----- = 3 x 5.5 x 30.4 x 12 ------ =, 4.819 Kwh

Load line loss --------------------------------------- = 5.86 Kwh

No-load line loss ------------------------------------ = .486 Kwh

Total yearly losses per customer -------------------- =290.165 Kwh

Total monthly losses per customer ------------------- = 24.18 Kwh

ANNUAL CHARGES

The well being of all living things depends mainly upon nourishing food and a public utility, or any enterprise, does not differ in this respect. In order to live, a continual replacement of those things which are being worn out must take place; it cannot continue to give service without an adequate return. What constitutes an adequate return cannot be definitely stated as conditions under which the service is given are not the same in all cases, but the return, in the agregate, must be sufficient to keep the enterprise going. The product cannot be sold at less than marginal cost to any purchaser without increasing the cost to others.

The total annual charges may be defined as the sum of all operating expenses plus interest and profit on the investment; or the total operatingcharges. These charges may be classified as "Investment costs", and "Production costs".

Investment Costs

Investment costs are composed of (a) Taxes; (b) insurance; (c) Depreciation; (d) maintenance; (e) interest; (f) profits.

Production Costs

The following divisions may be made in the production costs. (a) traffic; (b) transportation; (c) Operating; (d) commercial; (e) general.

Total Operating Charges

The following table shows the total annual or operating charges per KWh of two large central station companies whose combined production totals approximately three billion KWh yearly. Both these companies are, and have been engaged in extensive developement of rural service. The costs are in dollars.

	Charge	"A" Company	"B" Company	Average
1.	Generation	.00542	.00478	.0051
2.	Transmission	.00085	.00128	.001065
3.	Distribution	.00090	.00104	.000970
4.	Commercial	.00071	.00108	.000895
5.	New Business	.00016	.00020	.000180
6.	Utilization	.00046	.00090	.000680
7.	Taxes, Franch. etc.	.00292	.00252	.002720
8.	General (Depre. etc.)	.00418	.00499	.004585
Total		.0156	.01679	.016195

The first five (5) items of the above may be classed as production charges and the last three (3) as investment charges. Then -----

Production costs ---------------------------- = $ .00821

Investment charges -------------------------- = $ .007985

Average revenue (gross) per KWh -------------- = $ .0266

Average net revenue per KWh ----------------- = $ .010405

Summary of Operating Charges

If the gross revenue of $.0266 per Kwh. as shown on the preceding page represents the total operating charges plus a fair profit and interest on the investment it is obvious that a rural customer, whose share of charges should be highest per Kwh. used, cannot be charged less than this amount without being unfair to those of the customers whose share of the operating charge is small. The marginal price then that a rural customer should pay is $.0266 per Kwh. That this is only an apparent marginal price can be seen from the following computations.

The charge for customers losses should properly be the total operating charge which is the investment charge plus the production charge and which from the preceding page amounts to $.0162 per Kwh.

In the computations, the investment charge has taken as 12% on the total cost of the plant necessary to serve the customer and which includes interest, depreciation, taxes, maintenance, etc.

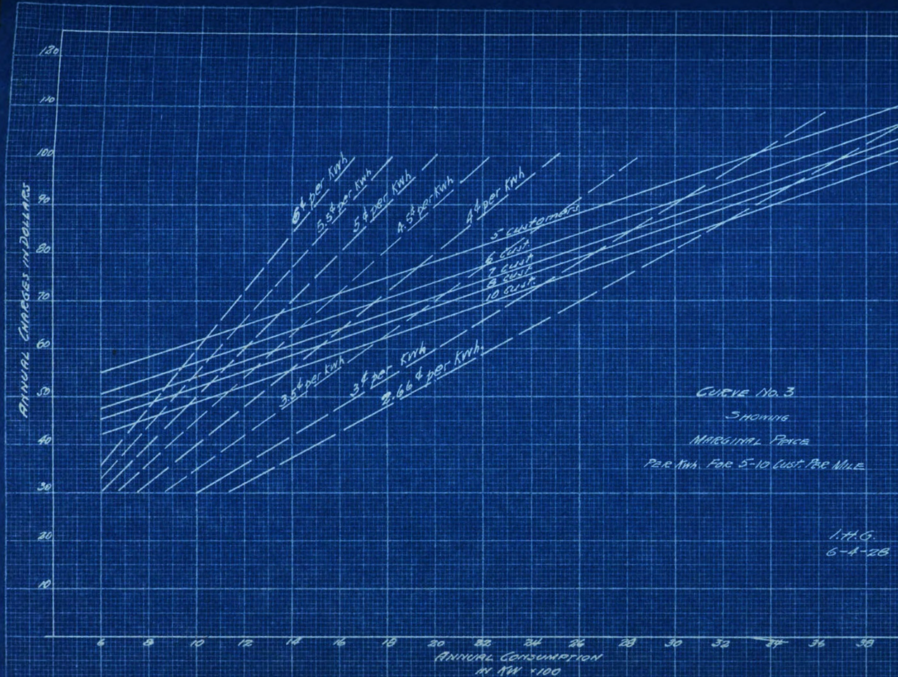
Cost of Service

In the following computations the line has been assumed to have 176 ft spacing between poles, (30 poles per mile) and the number of customers to be 5 per mile. The cost per customer under these conditions, including cost of the line, transformer installation, and service installation, is $337.35. (See page 13)

Investment charge = .12 x 337.35	=	$ 40.48
Cost of losses, 293 Kwh @ $.0162	=	4.75
Cost of energy, 913 Kwh @ $.0162	=	14.79
Total cost per customer	=	$ 60.02

If the customer is charged only the marginal cost of $.0266 per Kwh the total annual receipts would be 913 x .0266 = $24.28 which is 40% of the total cost. This marginal price can be reached only by increase of the number of customers causing a reduction of the fixed charges, by increaseing the consumption, or by a combination of the two.

Curves 3 and 4 show the effects of the increase of the number of customers per mile and increase of annual consumption. The marginal cost at any consumption would be the point of crossing of any rate line per Kwh, and the annual charge line. In developing these curves the effect of increase of transformer sizes has not been considered, as the difference would be almost negligible.


Curve No. 3
Showing
Marginal Price
Per Kwh. For 5-10 Cust. Per Mile
I.H.G.
6-4-28
Annual Charges in Dollars
Annual Consumption
in KW × 100
6¢ per Kwh
5.5¢ per Kwh
5¢ per Kwh
4.5¢ per Kwh
4¢ per Kwh
3.5¢ per Kwh
3¢ per Kwh
2.66¢ per Kwh.
5 customers
6 Cust.
7 Cust.
8 Cust.
10 Cust.
120
110
100
90
80
70
60
50
40
30
20
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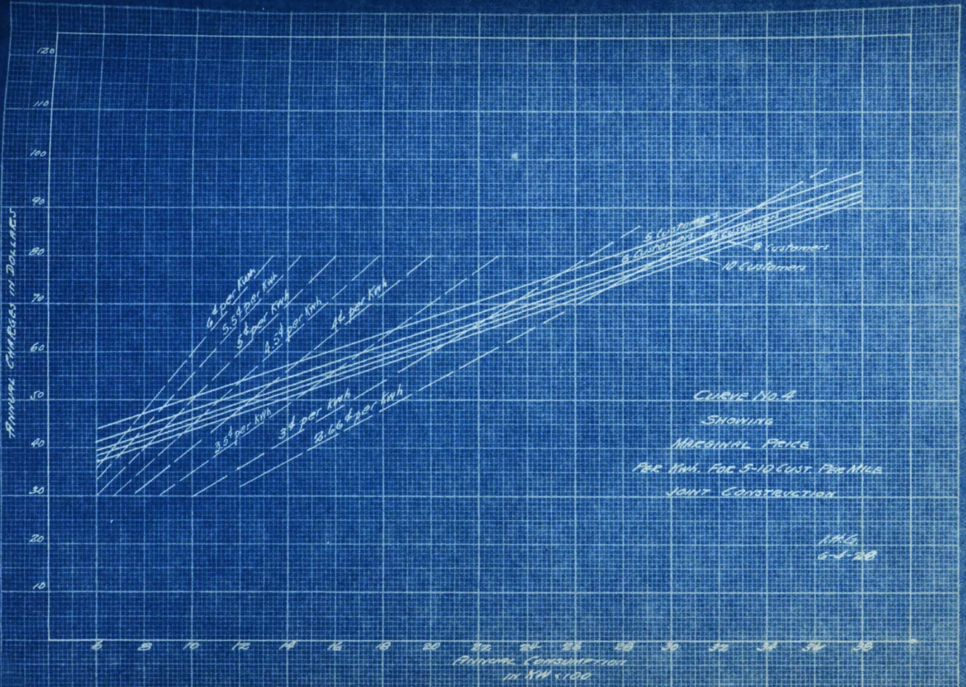

Curve No. 4
Showing
Marginal Price
Per Kwh. For 5-10 Cust. Per Mile
Joint Construction
R.H.G.
6-4-28
Annual Charges in Dollars
Annual Consumption in KW × 100
6¢ per Kwh
5.5¢ per Kwh
5¢ per Kwh
4.5¢ per Kwh
4¢ per Kwh
3.5¢ per Kwh
3¢ per Kwh
2.66¢ per Kwh
5 Customers
8 Customers
10 Customers

Reduction of Annual Charges

The investment charge is shown on page 30 to be the major item in the cost of service, and this is the only item that can be reduced in order to decrease the annual charge. A reduction in the energy cost will have little effect and the losses cannot be reduced without a reduction in the transformer size.

There are several ways in which this investment charge may be reduced. At fisst thought it would seem that the use of less costly construction materials will accomplish this and it will if the use of such materials does not shorten the life of the line beyond the point where the saving in first cost is not counterbalanced by the increasing rate of investment charge. The use of cheap materials not only shortens the life of the plant but also tend, to decrease the service to the customer through interruptions etc. thereby lessening his good-will towards the central station company and acting as a deterrent in the growth of consumption.

Cheap labor will usually do slip-shod work but high priced labor may be cheap if the output is increased without decreasing the quality. If a worker is paid a full day's pay he should give in return a full day's work. This is very often not the case. Some companies allow their men travel time to and from work and on rural lines especially, where the distances from the shop to the work are usually considerable, this will cause a large decrease in the daily output. This travel time will, at times, cause an increase of from 50% to 100% in the labor cost above that which it should cost if the men reported on the job.

Comparing the costs as shown on pages 10 to 14 inclusive and their accompanying curve it can be seen that a very material saving in the investment may be had by the use of joint construction. This joint use of pole lines is to be recommended in rural toritories where the load on will not amount to a great deal.

CONCLUSION

This work has been prepared with the thought that the cost of service is the determining factor of the rate to be charged. Rates cannot, of course, be based upon the cost of service to the individual, the individuals must be placed in groups, in districts, and in toritories, where one rate may be made applicable to all, these groups classed again according to the density of the load and a fair and just rate charged each group.

It is apparent that the rates for rural service must be higher than those charged in the more densely loaded districts. Its costs more to give the service, the customer expects to pay more, and it is an economic thruth.

It is not the purpose of this work to say what rates shall be charged. The cost of service differs so widely in different parts of the country that the rates used by one company cannot be applied by another. Then, too, there are so many different ways of rate making that it would be impossible for any one person to make a rate that would be accepted by all. The writer has endeavored to show that the cost of service is all-important and that there is a true marginal price which the customer must pay.