電工技術參考資料

變壓器及整流器類

龍門聯合書局印行

前　　言

"電工技術參考資料"不一定限於 A.I.E.E. 的論文彙集. 這六册取材於此,將來還可以選輯其他各國的論文資料,尤其是蘇聯和歐洲新民主主義國家的技術資料,或者照印原文,或者謹愼翻譯,都是電機工程師們當前重要的工作. 這六册書不過是開其端而已.

歐美的技術規範,設計數據,製造方法,决不能搬來就應用. 尤其是其中的經驗公式,其常數不一定可以完全適用於我國,必須通過我們自己的試驗與審查,方能決定其適用與否. 所以這些資料,可供"參考",而不必盡可"採用"

這六册書的範圍,只限於目錄中的六類,卽(1)總類,(2)變壓器及整流器類,(3)同期電機及直流電機類,(4)感應電動機類,(5)開關控制設備類,(6)工業應用及電氣測驗類. 其餘如發電廠,電力輸送,配電,電光照明,電訊工程,均未能同時選輯,頗爲遺憾.

選輯工作者二十人是自動集合的,委託龍門聯合書局影印. 選輯過程中,如有疏忽錯誤之處,請讀者加以指正. 配購印刷此書的紙張時,蒙中國電機工程學會上海分會予以協助,於此謹致其感謝.

1952 年元旦

CONTENTS

(Selections From A.I.E.E. Transactions)

1936 A.I.E.E. TRANSACTION VOLUME 55

1937 A.I.E.E. TRANSACTION VOLUME 56

1938 A.I.E.E. TRANSACTION VOLUME 57

1939 A.I.E.E. TRANSACTION VOLUME 58

1940 A.I.E.E. TRANSACTION VOLUME 59

1941 A.I.E.E. TRANSACTION VOLUME 60

1942 A.I.E.E. TRANSACTION VOLUME 61

1943 A.I.E.E. TRANSACTION VOLUME 62

1944 A.I.E.E. TRANSACTION VOLUME 63

1945 A.I.E.E. TRANSACTION VOLUME 64

1946 A.I.E.E. TRANSACTION VOLUME 65

1947 A.I.E.E. TRANSACTION VOLUME 66

1948 A.I.E.E. TRANSACTION VOLUME 67—PART I

1948 A.I.E.E. TRANSACTION VOLUME 67—PART II

1949 A.I.E.E. TRANSACTION VOLUME 68—PART I

1949 A.I.E.E. TRANSACTION VOLUME 68—PART II

1950 A.I.E.E. TRANSACTION VOLUME 69—PART I

1950 A.I.E.E. TRANSACTION VOLUME 69—PART II

SELECTIONS FROM A.I.E.E. TRANSACTION

VOL. 55 —— 1936

High Power Audio Transformers

A brief outline of the essential characteristics of high power audio transformers for class B amplification (tubes connected in push-pull fashion with their grid voltages of such value that the anode current is zero when there is no signal) is given here together with a brief description of the units used in the third and fourth stages of radiobroadcast station WLW.

By
J. F. PETERS
FELLOW A.I.E.E.
Westinghouse Elec. and Mfg. Co., East Pittsburgh, Pa.

HIGH POWER audio transformers do not differ materially from large transformers for converting power at 60 cycles. They differ principally in physical proportions of copper and iron, and require greater care in minimizing the internal distributed capacitance.

Since an audio transformer must operate over a wide range of frequencies and be capable of handling the full output at any one frequency or any combination of frequencies, the problem of obtaining sufficiently low leakage reactance and sufficiently low magnetizing current is the reason for making the proportions different from those of transformers for use at commercial power frequencies. The leakage reactance must be made sufficiently low to give good performance at high frequency, and the magnetizing current must be made sufficiently low to give good performance at the low frequency end of the range. To produce sufficiently low reactance to give satisfactory operation at high frequencies requires using a small number of turns for a given voltage, which results in a magnetic circuit of relatively large cross section. To obtain sufficiently low magnetizing current at low frequencies still further increases the cross section of the magnetic circuit.

These transformers are supplied by tubes that pass current in only one direction, and generally it is not possible to maintain a perfect balance between the 2 tubes supplying the alternate half cycles. This results in the equivalent of a direct current flowing through the primary winding. In order to prevent the unbalance of current from producing a heavy biased magnetic flux in the core, air gaps were provided in the units described later in this paper. Although air gaps in the core increase the alternating magnetizing current, they make it possible to design the core and coils so that the iron does not become saturated and produce harmonics in the magnetizing current.

The effective resistance of the windings of these transformers is low, first, because of the relatively small number of turns resulting in a small number of ampere-turns and therefore low-density leakage magnetic field cutting the conductors; and second, because the conductors are made of small dimensions in the direction at right angles to the flux lines, thus resulting in a low ratio between high frequency resistance and low frequency resistance.

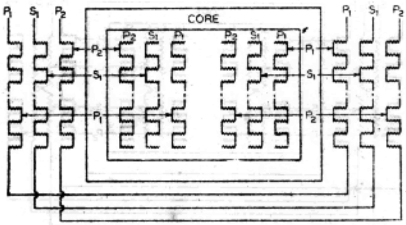

Fig. 1. Schematic diagram showing arrangement of windings in 180 kw fourth stage transformers

P and *S* designate primary and secondary windings, respectively

Fig. 2. One of the 180 kw fourth stage transformers out of its case

In producing the total output for radiobroadcast station *WLW*, 4 stages of amplification are required. Only the last 2 stages are described here, the first 2 stages being of quite small output. In determining the maximum permissible reactance for each of the last 2 stages, the total permissible value was determined and it then was proportioned between the 2 units in the manner that would meet most easily the maximum permissible value.

A paper recommended for publication by the A.I.E.E. committee on communication, and scheduled for discussion at the A.I.E.E. winter convention, New York, N. Y., Jan. 28–31, 1936. Manuscript submitted Oct. 2, 1935; released for publication Nov. 20, 1935.

It is desirable to have the output of the combined amplifying stages reproduce accurately all input frequencies in their relative magnitudes. It is of course not practical to accomplish this. Freedom from distortion is more important in certain parts of the frequency range than in others. Distortion in frequencies below 100 cycles and above 10,000 cycles, if not excessive, does not alter seriously the quality of reproduction. When designing the audio transformers for station *WLW*, the quality desired necessitated limiting the distortion to 5 per cent

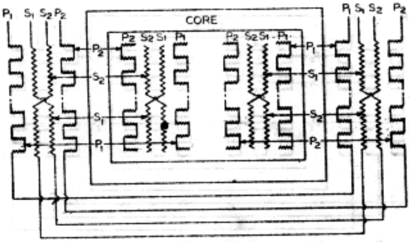

Fig. 3. Schematic diagram showing arrangement of windings in 7$^1/_2$ kw third stage transformers

P and *S* designate primary and secondary windings, respectively

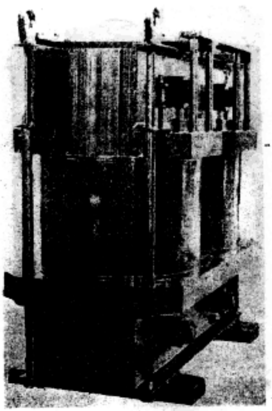

Fig. 4. A complete 7$^1/_2$ kw third stage transformer

between 100 and 5,000 cycles and to 22 per cent at 30 cycles and at 10,000 cycles.

The requirements of reproducibility at the high frequency end of the range have more influence on the design of the transformers than do those at the low frequency end. The leakage reactance in the units, which is proportional to frequency, reduces the amplitude of delivered voltage. The load on the transformers is made up of various frequencies superimposed; but by limiting the reactance to such a value that the distortion will not exceed 22 per cent when supplying full load at 10,000 cycles, then when the load consists of a combination of frequencies, none of any appreciable magnitude exceeding 10,000 cycles, the required performance specifications will be met.

The circuits that the transformers feed into have the characteristics of a resistance; therefore, they supply loads at unity power factor. The regulation of the units as calculated for unity power factor at their rated loads then is a measure of their amplitude performance.

The total regulation at 22 per cent at 10,000 cycles was split arbitrarily 13 per cent for the fourth stage and 9 per cent for the third stage. The maximum permissible reactance for the fourth stage then was square root of $[100^2 - (100 - 13)^2]$ or 49 per cent and for the third stage 41 per cent, when delivering the full output of the units at 10,000 cycles. It was found when designing the units that the 49 per cent on the large unit could be appreciably lower, with the result that the combined errors of the 2 stages at 10,000 cycles should not exceed 14 per cent.

Performance tests were not made on individual transformers. Tests on the complete combination of all stages including the transformers and tubes indicated excellent results.

The fourth stage audio transformer for station *WLW* has a nominal rating of 180 kw. This unit has 2 input or primary windings each for 10,200 volts (crest) and one secondary or output winding of 6,000 volts (crest). The arrangement of the windings is indicated by figure 1, and the unit out of its tank is shown in figure 2. Since the 2 primary windings are supplied by separate tubes and therefore receive current on alternate half cycles, it was necessary to interlace these 2 windings symmetrically with the secondary winding. All 3 windings consist of circular pancake coils. Each primary winding consists of a stack of coils on each leg of the transformer as shown by figure 1. The stack of coils having the larger diameter on one leg is connected in series with the stack having the smaller diameter on the other leg, the secondary winding being between the inner and outer primary windings. All 3 windings are made of thin copper ribbon. The individual primary coils consist of 2 turns each, and the secondary coils of 3 turns each.

The assembled unit as shown in figure 2 weighs 27,000 pounds. Some idea of the proportion of copper and iron can be obtained from the fact that of the 27,000 pounds, the magnetic circuit contains 25,700 pounds of sheet steel. This transformer is placed in a boiler-iron tank and operates in oil.

The third stage transformers have a nominal rating of 7$^1/_2$ kw each, 2 of these units being required for this stage. Each of these transformers has 2 primary and 2 secondary windings. The 2 primary windings are supplied from separate tubes, and the 2 secondary windings supply the grid voltage to the tubes for the fourth stage. The 2 primary windings receive current in alternate half cycles and must feed into each of the secondary windings; therefore, it was necessary to interlace all 4 windings. The arrangement of the windings is shown by figure 3.

The secondary windings are made up of single-layer helical coils. The coils are broken in the center and cross-connected so that on each leg the average coupling to the primary windings is the same for both windings. The 2 primary windings are made up of pancake coils. One of these units is shown in figure 4. They are insulated and are not placed in a container. Their total weight is 4,200 pounds each.

Distribution Transformer Lightning Protection Practices

By
L. G. SMITH
FELLOW A.I.E.E.
Consolidated Gas, Electric Light & Power Co., Baltimore, Md.

With the object of determining the effectiveness of the newer methods of protecting distribution transformers from lightning, a survey of operating data obtained during 1934 by 38 electric power companies has been made by the transmission and distribution committee of the Edison Electric Institute. The results of this survey are presented herewith. In general, interconnection of the lightning arrester ground with the secondary neutral has been found superior to other methods of protection.

IN RECENT YEARS various methods of protecting distribution transformers have been devised with the object of reducing transformer failures and blowing of primary fuses during lightning storms. To obtain operating data on these newer methods in comparison with the conventional method of protecting distribution transformers, a survey was made by the transmission and distribution committee of the Edison Electric Institute. This consisted of collecting operating data for the year 1934. It is planned to continue the collection of these data. At the present time similar data are being collected for the year 1935.

A paper recommended for publication by the A.I.E.E. committee on protective devices, and scheduled for discussion at the A.I.E.E. winter convention, New York, N. Y., Jan. 28–31, 1936. Manuscript submitted Oct. 17, 1935; released for publication Nov. 23, 1935.

On the basis of data collected in 1934, the following conclusions appear to be justified:

1. Interconnection seems to be superior to other methods of lightning protection of distribution transformers.

2. The use of the common neutral system as a means of generally obtaining low ground resistance for interconnection appears promising.

3. Low ground resistance is believed to be one of the most important factors in improving lightning protection.

4. Interconnection does not seem to increase the duty on lightning arresters or their rate of failure.

Various Methods of Lightning Protection

Figures 1 to 5 illustrate the various methods used in the lightning protection of distribution transformers. The interconnection system, shown in figure 2, which nominally consists of a solid tie between the lightning arrester ground and the secondary neutral, may be modified by the insertion of gap *A*; by a gap (*B*) tying the ground to the case; or by a combination in which both gaps *A* and *B* are used. It is interesting to note that 34 out of 38 companies from which operating data have been obtained are using interconnection to some extent.

Results—1934 Lightning Season

Operating data for the 1934 lightning season from 38 companies have been summarized in table I. The data have been combined in an attempt to obtain totals that would tend to eliminate the effect of uncontrolled variables. The combined data are included in table II. It may be noted that the ground resistance is a variable for which compensation can-

Table I—Summary of Operating Data for 1934 for Various Methods

Company	1	2	3	4	4	5	6	6	7	7	7
Interconnection											
Solid or gap used?	Used scheme, but no data available	Solid	Solid	Solid	Gap	Solid	Solid	Gap		Solid	
Number of installations		3,708	b	537	521	10,000a	4,652	646		28	
Type of territory		U.S.		S.	U.S.R.		S.R.	S.R.		R.	
Average ground resistance—ohms		3	1½	25	50	5	5	5		8.7	
Primary fuses blown—per cent		0.94	No data available as yet	18.2	8.25	General improvement noted	1.58	3.13		0.0	
Ratio—change over standard connection—per cent		100.0		198.5	90.0		81.54	161.3		0.0	
Transformer winding failures—per cent		0.135		0.37	0.193		0.161	0.156		0.0	
Ratio—change over standard connection—per cent		69.9		40.2	21.0		80.54	78.0		0.0	
Lightning arrester failures—per cent		0.0		N.D.	N.D.		N.D.	N.D.		3.37	
Ratio—change over standard connection—per cent		0.0								102.13	
Troubles on customer's premises—per cent*		0.0		0.4	0.0		N.D.	N.D.		N.D.	
Ratio—change over standard connection—per cent				445.0	0.0						
Meters burned out—per cent*		0.323		0.4	0.0		N.D.	N.D.		N.D.	
Ratio—change over standard connection—per cent		83.7		364.0	0.0						
Surgeproof Transformers											
Number of installations	60	None	None	176		34	10			551	
Type of territory	R.			U.S.R.		R.	S.			S.R.	
Average ground resistance—ohms	20.0			125.0 Ω		5.0	250.0			95.6	
Is check made to find gap failures?	No.			No.		No.	No data; installed latter part of 1934			Yes.	
Primary fuses blown—per cent	0.0			4.55		0.0				9.78	
Ratio—change over standard connection—per cent	0.0			49.7						91.9	
Transformer winding failures—per cent	0.0			0.0		0.0				0.184	
Ratio—change over standard connection—per cent	0.0			0.0						35.4	
Deion gap failures—per cent	0.0			0.07		N.D.				1.99	
Ratio—change over standard connection—per cent	0.0			0.0						60.2	
Troubles on customer's premises—per cent*	0.0			0.0		0.0				N.D.	
Ratio—change over standard connection—per cent				0.0							
Meters burned out—per cent*	0.0			1.14		0.0				N.D.	
Ratio—change over standard connection—per cent				1,036.0							
3 Point Connection											
Number of installations	None	None	None	None		None	None		62		50
Type of territory									R.		R.
Average ground resistance—ohms									80.0		21.0
Primary fuses blown—per cent									11.5		6.0
Ratio—change over standard connection—per cent									108.0		56.3
Transformer winding failures—per cent									0.0		0.0
Ratio—change over standard connection—per cent									0.0		0.0
Lightning arrester failures—per cent									12.8		6.0
Ratio—change over standard connection—per cent									388.0		181.9
Troubles on customer's premises—per cent*									N.D.		N.D.
Ratio—change over standard connection—per cent											
Meters burned out—per cent*									N.D.		N.D.
Ratio—change over standard connection—per cent											
Standard Connection											
Number of installations	4,150	3,623	5,807	8,222		15,000	516e		50f	130e	18,182
Type of territory	U.S.R.	U.S.R.	U.S.				U.S.		R.	R.	U.S.R.
Average ground resistance—ohms	15.0	50.0	N.D.	25–200		5–400	250.0		90.0	46	130.
Primary fuses blown—per cent	13.45	0.94	2.14	9.16		N.D.	1.94		10.0	27.7	10.65
Transformer winding failures—per cent	0.29	0.193	0.96	0.92		N.D.	0.20		0.0	0.77	0.52
Lightning arrester failures—per cent	0.60	0.138	N.D.	0.06		N.D.	N.D.		N.D.	N.D.	3.3
Troubles on customer's premises—per cent*	0.0	0.0	N.D.	0.09		N.D.	N.D.		N.D.	N.D.	N.D.
Meters burned out—per cent*	7.08	0.386	N.D.	0.11		N.D.	N.D.		N.D.	N.D.	N.D.

Company	19	19	20	21	22	23	24	25	26	27	28
Interconnection											
Solid or gap used?	Solid	Gap	Solid	Solid	Solid	Solid					Solid
Number of installations	144	72	1,300	4,582	A few	1,919	None	None	None	None	434
Type of territory	U.S.R.	R.	U.S.	U.S.R.		U.					U.S.R
Average ground resistance—ohms	30.0	30.0	0.25	9.8	N.D.	1.0					
Primary fuses blown—per cent	5.6	7.2	1.46	0.15	N.D.	0.104					0.23
Ratio—change over standard connection—per cent	63.6	81.8	53.1	3.72		9.04					
Transformer winding failures—per cent	2.78	0.0	0.08	0.0	N.D.	0.052					
Ratio—change over standard connection—per cent	264.0	0.0	62.5			∞					
Lightning arrester failures—per cent	1.20	1.30	0.0	0.086	N.D.	0.0					0.46
Ratio—change over standard connection—per cent	158.0	158		1.64		0.0					
Troubles on customer's premises—per cent*	0.0	0.0	0.0	0.0	N.D.	0.0					0.0
Ratio—change over standard connection—per cent											
Meters burned out—per cent*	0.0	0.0	0.0	0.0	N.D.	0.0					1.62
Ratio—change over standard connection—per cent	0.0	0.0									
Surgeproof Transformers											
Number of installations	20		15	None	50	6	5	8	None	None	None
Type of territory	R.				R.	S.R.	R.	U.S.R.			
Average ground resistance—ohms	43.0				10.0	20.0	20.0	12.0			
Is check made to find gap failures?	No.				No.	Yes.	No.	No.			
Primary fuses blown—per cent	13.7				0.0	20.0	N.D.	N.D.			
Ratio—change over standard connection—per cent	155.8				N.D.	1,739.0					
Transformer winding failures—per cent	0.0				0.0	0.0	0.0	0.0			
Ratio—change over standard connection—per cent	0.0				0.0						
Deion gap failures—per cent	3.45				0.07	0.0	0.07	0.07			
Ratio—change over standard connection—per cent	392.0				N.D.	0.0					
Troubles on customer's premises—per cent*	0.0				0.0	0.0	0.0	0.0			
Ratio—change over standard connection—per cent					N.D.						
Meters burned out—per cent*	0.0				N.D.	0.0	0.0	0.0			
Ratio—change over standard connection—per cent	0.0										
3 Point Connection											
Number of installations	None		None	None	100	None	None	20	None	None	None
Type of territory					U.S.R.			U.S.R.			
Average ground resistance—ohms					10.0			12.0			
Primary fuses blown—per cent					N.D.			N.D.			
Ratio—change over standard connection—per cent											
Transformer winding failures—per cent					0.0			0.0			
Ratio—change over standard connection—per cent					0.0						
Lightning arrester failures—per cent					N.D.			0.0			
Ratio—change over standard connection—per cent											
Troubles on customer's premises—per cent*					0.0			0.0			
Ratio—change over standard connection—per cent											
Meters burned out—per cent*					N.D.			0.0			
Ratio—change over standard connection—per cent											
Standard Connection											
Number of installations	569		4,700	124	1,400	3,481	None	1,500	4,500	14,500	None
Type of territory	U.S.R.		U.S.R.	U.S.R.	U.S.R.	U.S.R.		U.S.R.	U.S.R.	U.S.R.	
Average ground resistance—ohms	30.0		35.0	12.2	10.0	38.0		12.0	80.0	N.D.	
Primary fuses blown—per cent	8.8		2.75	4.03	N.D.	1.15		N.D.	N.D.	N.D.	
Transformer winding failures—per cent	1.05		0.128	0.0	0.714	0.0		N.D.	2.44	0.248	
Lightning arrester failures—per cent	0.88		0.0	4.03	N.D.	0.029		N.D.	N.D.	N.D.	
Troubles on customer's premises—per cent*	0.0		0.0	0.0	N.D.	0.0		N.D.	N.D.	N.D.	
Meters burned out—per cent*	0.703		0.0	0.0	1.85	0.0		N.D.	N.D.	N.D.	

of Protecting Distribution Transformers From Lightning

8		9	Solid		10	11	12	13	14		15	16		17	18
Solid	Gap	Y	Δ	Total	Solid	Solid	Solid	Solid	Solid	Gap	Solid	Solid	Gap	Solid	Solid
154	61	3,575	3,536	7,111	12,000	4,709	3,175	1,934	97	98	4,143	900	600	9	427
R.S.	R.S.	U.	U.S.R.		U.S.	U.	U.S.	S.R.	R.	R.	U.S.			U.S.	U
70	70	10	120		0.5	0.6	1.0	2.0	22.8	101.0	N.D.	25.0	25.0	10.5	3.0
N.D.	N.D.	6.1	32.3	19.1	0.295	0.064	0.72	0.164	10.3	9.2	0.94	N.D.	N.D.	N.D.	0.47
		22.2	64.2	44.7	26.5			44.1	52.5	47.0	12.0				
N.D.	N.D.	0.78	1.73	1.25	0.067	0.042	0.22	0.103	1.03	0.0	0.64	N.D.	N.D.	N.D.	0.7
		26.2	63.9	45.0	47.7			103.0	100.0	0.0	17.3				
N.D.	N.D.	N.D.	N.D.	N.D.	0.141	0.021	0.22	0.164	1.03	0.0	0.048	N.D.	N.D.	N.D.	0.0
					164.1			102.6	+∞		14.5				
N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.0	0.0	0.0	0.0	0.0	N.D.	0.0	0.0	0.0	0.0
														0.0	
N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.021	0.22	0.0	0.0	0.0	0.37	0.0	0.0	0.0	0.0
														0.0	
3			99		None	None	None	None	11		591	30		12	A few
S.R.									R.		S.R.			R.	
N.D.			200.0						66.5		N.D.	25.0		10.5	
Yes			Yes						No		No	N.D.		Yes	
N.D.			1.01						9.1		0.34	0.0		16.67	
			2.0						46.4		4.45			487.0	
N.D.			0.0						0.0		1.01	0.0		0.0	
			0.0						0.0		29.2			0.0	
N.D.			16.16						0.0?		3.05?	N.D.		16.67	
											925.0			4,900.0	
N.D.			0.0						0.0		N.D.	0.0		0.0	
														0.0	
N.D.			0.0						0.0		N.D.	N.D.		0.0	
														0.0	
None					None	None	None	None	None		None	None		None	20f
															R
															3.0
															5.0
															5.0
															0.0
															0.0
															0.0
4,000		3,575	7,405	10,980	10,200	None	None	1,992	97		9,287	13,255		6,795	None
U.S.R.					U.S.			S.R.	R.		S.R.			U.S.R.	
70.0		50.0	60.0	60.0	14.0			30.0	93.5		N.D.	25.0		19.45	
2.75		27.4	50.3	42.8	1.11			0.35	19.6		7.8	N.D.		3.42	
0.875		2.97	2.71	2.79	0.14			0.1	1.03		3.464	1.1		0.12	
0.375		N.D.	N.D.	N.D.	0.086			0.15	0.0		0.33	N.D.		0.34	
N.D.		N.D.	N.D.	N.D.	N.D.			0.0	0.0		N.D.	0.0		0.015	
2.50		N.D.	N.D.	N.D.	N.D.			0.0	0.0		N.D.	N.D.		0.472	

29	30	31	32	33	34		35	36	37	38	Total		
Solid	Solid[m]	Solid	Solid	Solid	Solid	Gap	Gap	Both	Solid	?	Solid	Gapped	Both
20	29,760	50	6,851	866	44	57	193	11,122	2,063	202	105,529	1,583	107,112
U.S.R.	U.S.R.	U	U.S.R.	U.	U.	U.	R.	U.S.R.	U.	S.			
1.9	10.0	N.D.	1.0	30.0	0.0	0.0	N.D.	N.D.	10.0	15–100	14.4	37.2	18.3
0.0	2.79[n]	N.D.	0.51	1.50	4.88	0.0	30.0	2.37	1.02	0.97	2.77	8.72	2.85
0.0	102.5			11.1	125.3	0.0	53.5	33.9	53.7	19.1	32.7	103.1	33.6
0.0	0.477	N.D.	0.0875	0.116	0.0	0.0	N.D.	N.D.	0.295	0.330	0.840	0.379	0.341
0.0	308.0			14.5	0.0	0.0			57.7	31.1	44.3	46.1	41.5
0.0	2.385[n]	N.D.	0.614	N.D.	0.0	0.0	N.D.	N.D.	N.D.	N.D.	1.06	0.441	1.06
	110.0										64.1	26.6	64.0
0.0	N.D.	0.0	0.0	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.			
0.0													
0.0	N.D.	0.0	0.146	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.130	0.0	0.127
0.0										50.04	10.65	0.0	10.4
18	4	None	None	96	14		None	71	None	37		1,994	
S.R.	R			R.	U.			S.R.					
N.D.	10.0			N.D.	N.D.			2.8				75.1	
No	No data recorded			No	No					No data available			
0.0				2.085	0.0			0.0				3.77	
0.0				15.4	0.0			0.0				44.5	
0.0				0.0	0.0			0.0				0.353	
0.0				0.0	0.0							42.9	
0.0				0.0	0.0			0.0				2.27	
												137.3	
0.0				0.0	N.D.			0.0					
0.0													
0.0				0.0	N.D.			0.0				0.261	
0.0												21.4	
None	None	None	None	22	None		None	None	None	None		154	
				R									
				N.D.								18.8	
				0.0								7.08	
				0.0								83.6	
				0.0								0.365	
				0.0								44.3	
				0.0								6.32	
												382.0	
				0.0									
				0.0								0.0	
												0.0	
5,200	15,172	5,380	None	4,366	3,362		51	4,053	3,601	473[e]		165,914	
U.S.R.	U.	U.S.R.		U.R.	U.		R.	U.S.R.	U.	S.R.			
30.0	15.0	30.0		N.D.	N.D.		N.D.	N.D.	10.0	15–100		69.6	
5.76	2.72[n]	2.23		13.52	3.895		56.0	6.99	1.9	5.07		3.46	
0.385	0.156	0.075		0.801	0.635		N.D.	N.D.	0.511	1.06		0.823	
N.D.	2.17[n]	N.D.		N.D.	0.0		N.D.	N.D.	N.D.	N.D.		1.653	
0.25	N.D.	N.D.		N.D.	N.D.		N.D.	N.D.	N.D.	N.D.			
0.289	N.D.	N.D.		N.D.	N.D.		N.D.	N.D.	N.D.	N.D.		1.22	

a—Percentage based upon number of transformers involved.
b—Being installed 1934.
c—Approximate.
d—As compared with results with standard connection in surrounding area.
e—This includes data on 516 3 phase transformers and is not directly comparable with interconnection.
f—One ground rod salted
g—Ground resistance lowered to 30 ohms
h—Balance on system.
i—3-phase 4-wire system.
j—Delta system.
k—Includes both bushing and transformer winding failures.
l—On 13.2 kv system.
m—This company reports that the interconnections are in a much more exposed area than the area of the standard connections. The performance of the interconnections constituted a decided improvement over that of the standard connections previously used in the same area.
n—Delta system; lightning arrester failures and primary fuses blown are based upon number of transformers. If based upon number of lightning arresters, divide percentage of lightning arrester failures by 2.
o—3 years.
R—Located in rural sections.
S—Located in suburban sections.
U—Located in urban sections.
N.D.—No data.
By "ratio—change over standard connection" is meant the ratio of performance of one connection to that for the standard connection expressed in per cent.