208 Volt Systems And American National Standard C84.1

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Historical Background-Secondary Network Systems

Most of the 208Y/120 Volt system capacity in the United States is found in underground secondary networks supplying high-density commercial areas of our cities. The use of this type of distribution system is very extensive and probably will continue to be so for many years to come. Some utilities also provide 208Y/120 Volt service to large isolated commercial loads outside of secondary network areas, such as shopping centers and schools.

The first automatic a-c network system, as we are familiar with it today, was put into operation in New York City in 1922, more than fifty years ago. At that time the voltage level was 199Y/115 Volts. The network system had its inception under circumstances requiring highly dependable electric service, flexibility, and economy to serve a mixture of power and lighting loads. It was natural that its earliest applications were in the business sections of large cities supplanting the 3-wire, Edison d-c networks which had become unwieldly and uneconomical.

The increased use of the secondary network was rapid. Today they are used in about 90 percent of the cities in the country having a population of 100,000 or more and in about 1/3 of all cities with a population between 25,000 and 100,000.

A study of some of the A.I.E.E. papers presented in 1924 reveals that a basic part of the philosophy in selecting the four-wire, 199Y/115-Volt system was to permit the supply of service to standard single-phase and three-phase utilization equipment available at that time. Principal load components were 115-Volt incandescent lighting and 220-Volt, three-phase motors. The electrical "stiffness" of the network system resulted in generally acceptable performance of the 220-Volt motors, whereas this would not necessarily be true for 199Y/115-Volt radial systems.

Historical Background - Voltage Standardization

Voltage standardization dates back to the AIEE Standardization Rules of 1899, which served the needs of the industry for nearly 20 years, when it became apparent that revision was necessary. At this time the Electrical Apparatus Committee of the National Electric Light Association (NELA) prepared a report on transformer voltage standardization and issued it in 1922. These standards were adopted by the manufacturers and included in their catalogs as "Standard Voltage Ratings".

After a trial period, it became apparent that these standards did not entirely fulfill the requirements of the industry. Therefore the Electrical Apparatus Committee again took up the matter and recommended a revision of voltage standards which would take into account the entire electrical supply system from the utilization equipment to the generator. This led to the formation of a joint committee of the NELA and National Electrical Manufacturers Association (NEMA) which culminated in a schedule of voltage ratings published in 1930 in a document entitled "Preferred Voltage Ratings for A-C Systems and Equipment" (NELA Publication No. 043, NEMA Publication No. 100).

After a number of years of experience with this report, it again became evident that a revision was necessary because of factors such as:

(1) the upward trend of utilization voltages

(2) increasing use of networks

The revision was published in May 1949 as EEI Publication No. R-6, NEMA Publication No. 117, "EEI-NEMA Preferred Voltage Ratings for A-C Systems and Equipment." Subsequently in 1954 this standard was approved as an American Standards Association (ASA) Standard ASA C84.1-1954, the forerunner of the current ANSI C84.1-1975.

The first major revision of ASA C84.1-1954 was published in 1970 after approximately seven years of work by representatives from all sectors of the industry.

Early in the century, distribution voltages (and most of the higher voltages, as well) were multiples of 110 Volts. Thus, the prevelant single-phase distribution voltage for serving lighting and residential loads was 110/220 Volts, and 220 Volts was the predominant three-phase voltage for small power loads. The corresponding motor voltages were 110 and 220 Volts single-phase and 220 Volts three-phase.

Between 1900 and the 1940's, system voltages gradually inched up progressively from 110 to 115 and then to 120 Volts. By 1949 about 75 percent of the incandescent lamps sold were rated 120 Volts. Aside from the secondary network systems, distribution voltages generally were 120/240 Volts single-phase and 240 Volts three-phase. This resulted in the application of increasingly high voltage on the standard 110 and 220-Volt motors.

Shortly after its inception, the standard voltage for secondary network systems became 208Y/120 to more adequately serve 220-Volt motors. This undoubtedly stimulated the trend toward higher voltages.

Thus, the 220-Volt standard motor was being served by nominal system voltages as low as 208 Volts on the one hand and as high as 240 Volts on the other hand. Industry-wide recognition of the urgent need to stop this "inching-up" process was a major factor in the formulation of the EEI-NEMA document, "Preferred Voltage Ratings for A-C Systems and Equipment", published in 1949. This standard defined nominal system voltages and operating ranges.

Strict adherence to this standard and subsequent revisions by all segments of the industry during the past 25 years has effectively stopped the inching-up process.

However, in arriving at the current ANSI C84.1-1975 standard, several significant changes were made in motor and control standards in order to re-establish a harmonious relationship between motor voltages and supply system voltages.

Because of the trend to higher voltages, single-phase, fractional - and integral - horsepower motors were standardized at 115 and 230 Volts in 1941 on the basis that most of such motors will operate on 120/240-Volt systems. The 115-Volt motors are suitable for operation on 208Y/120-Volt secondary network systems. No changes were made in the three-phase motor ratings at that time. Single-phase 208-Volt motors were not considered at that time because users of motors on secondary network systems were expected to employ the 3-phase, 220-Volt motor.

However, when work began in 1963 on the last major revision of ANSI C84.1, it quickly became apparent that the principal conflict in the utilization area was between three-phase system and motor voltages. As a consequence, in 1968 the three-phase standard motor voltages were changed thus breaking the long-standing impasse. The present voltages of 230 and 460 were established, and a new three-phase rating of 200-Volts was introduced. The latter step was taken because operation of 230-Volt motors on 208-Volt systems is not recommended since the utilization voltage encountered will commonly be below the minus 10 percent tolerance on the voltage rating of the motor.

A single-phase motor rating of 200-Volts has not yet been standardized, but it seems logical to expect such a standard in the future.

Table C3 of ANSI C84.1 lists standard motor nameplate voltages and the corresponding system nominal voltages on which they are normally applied.

ANSI C84.1-1975

Status

The current edition of C84.1 is dated 1975; however, the last revision, issued in 1975, contained a few minor changes, mostly of an editorial nature.

An American National Standard implies a consensus of those substantially concerned with its scope and provisions. An American National Standard is intended as a guide to aid the manufacturer, the consumer, and the general public. The existence of an American National Standard does not in any respect preclude anyone, whether he has approved the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standard. The standards are formulated voluntarily by those sectors of the industry substantially concerned. Because American National Standards are subject to periodic review and revision, users should obtain the latest editions.

Scope

"This standard establishes voltage ratings for 60 Hz electric power supply and utilization systems above 100-Volts and through 230 kV together with operating tolerances from nominal voltages. It also makes recommendations to other standardizing groups with respect to voltage ratings for equipment used on power systems and for utilization devices supplied therefrom".

Definitions

The heart of the standard appears essentially on two printed pages, the first devoted to fundamental definitions and description of voltage ranges, and the second consisting of a numerical table of nominal system voltages and voltage ranges. Much of the following information is quoted directly from the standard.

Nominal Voltage of a Circuit or System

"A nominal value assigned to the circuit or system for the purpose of conveniently designating its voltage class". In other words the nominal voltage is more or less a name assigned to the circuit or system.

Service Voltage

"The voltage at the point where the electric systems of the supplier and the user are connected". This is the voltage delivered to the user by the supplier, thus defining the responsibility of the supplier.

Utilization Voltage

"The voltage at the line terminals of utilization equipment". Specification of utilization voltage levels requires that the user shall so design and operate his system to provide satisfactory voltage at his utilization equipment when the service voltages are within specified limits.

Voltage Ranges

"For any specific nominal voltage, the voltages actually existing at various points at various times on any power system, or on any group of systems, or in the industry as a whole, will be distributed by percentage in a manner such as indicated in Fig. 1".

An important part of the early work in connection with the review and revision of ANSI C84.1-1954 consisted of a comprehensive questionnaire on power system design and operating practices including approximately 65,000 measurements of actual service voltages in all parts of the United States and from systems of all sizes. The results of this survey not only confirmed the concept illustrated in Fig. 1, but also indicated that C84.1 had effectively ended the inching-up process in service voltages. Mode voltage readings (most frequent) taken on 120, 208, and 240-Volt systems were 120, 210, and 240 respectively. Corresponding average voltages were 120.9, 211.0, 241.5 Volts respectively. Replies to the questions on system design practices indicated that the utilities were indeed following the recommendations of C84.1.

"It is important that the design and operation of power systems and the design of equipment to be supplied from such systems be coordinated with respect to these voltage variations so that, insofar as practical, the equipment will perform satisfactorily throughout the range of actual utilization voltages that will be encountered on the systems. In order to further this objective, this standard establishes for each nominal system voltage two ranges for service and utilization voltage variations, designated as Range A and Range B --. These limits apply to sustained voltage levels and not to momentary voltage exclusions that may result from such causes as switching operations, motor starting currents, etc".

<u>Range A - Service Voltage</u>

"Electric supply systems shall be so designed and operated that most service voltages are within the limits specified for this range. The occurrence of service voltages outside of these limits is to be infrequent".

For the two four-wire utilization voltage levels 208Y/120 and 240/120 Volts, Minimum Range A Voltages are specified as 197Y/114 and 228/114 Volts respectively. The corresponding maximum values are 218Y/126 and 252/126 Volts.

<u>Range A - Utilization Voltage</u>

"User systems shall be so designed and operated that with service voltages within Range A limits, most utilization voltages are within the limits specified for this range".

"Utilization equipment shall be designed and rated to give fully satisfactory performance throughout this range".

Again, for the 208Y/120 and 240/120-Volt systems, the Minimum Range A utilization voltages are specified as 191Y/110 and 220/110 Volts respectively. Maximum Range A utilization voltages are ~~the same values as Maximum Range A service voltages, namely~~ 217Y/125 and 250/125 Volts respectively.

<u>Range B - Service and Utilization Voltages</u>

"This range includes voltages above and below Range A limits that necessarily result from practical design and operating conditions on supply or user systems, or both. Although such conditions are a part of practical operations, they shall be limited in extent, frequency, and duration. When they occur, corrective measures shall be undertaken within a reasonable time to improve voltages to meet Range A requirements.

"Insofar as practicable, utilization equipment shall be designed to give acceptable performance in the extremes of this range of utilization voltages, although not necessarily as good performance as in Range A".

The pertinent numerical values for Range B are specified as:

VOLTAGE RANGE B

	MINIMUM		MAXIMUM
Nominal System Voltage	Utilization Voltage	Service Voltage	Utilization and Service Voltage
208Y/120	184Y/106	191Y/110	220Y/127
240/120	212/106	220/110	254/127

"It must be recognized that, because of conditions beyond the control of the supplier or user, or both, these will be infrequent and limited periods when sustained voltages outside of Range B limits will occur. Utilization equipment may not operate satisfactorily under these conditions, and protective devices may operate to protect the equipment. When voltages occur outside the limits of Range B, prompt corrective action is recommended. The urgency for such action will depend on many factors, such as location and nature of load or circuits involved, and magnitude and duration of the deviation beyond Range B limits".

The above values for Range B are taken from Table I of the standard and apply to systems serving combined power and lighting loads. However Note c recognizes that slightly lower values of minimum utilization voltages can occur on circuits not supplying lighting loads. These values are:

Nominal System Voltage	Range A	Range B
208	187	180
240	216	208

The occurrence of these lower minimum utilization voltages is a matter of building wiring design since C84.1 does not recognize lower service voltages than those in Table I.

Appendix C of C84.1 lists voltage ratings for various kinds of utilization equipment and the nominal system voltages on which the equipment normally is applied. The voltage ratings of equipment are taken from appropriate industry standards, while the nominal system voltages are from C84.1. It should be noted that appendices are not a formal part of ANSI standards but are included as convenient supplementary reference material only.

Table C2 applies to heating, refrigeration, and air-conditioning equipment and is reproduced below.

As indicated in the first footnote, the parenthetical values of equipment nameplate voltage ratings were under consideration for future designs at the time the revision of C84.1 was completed.

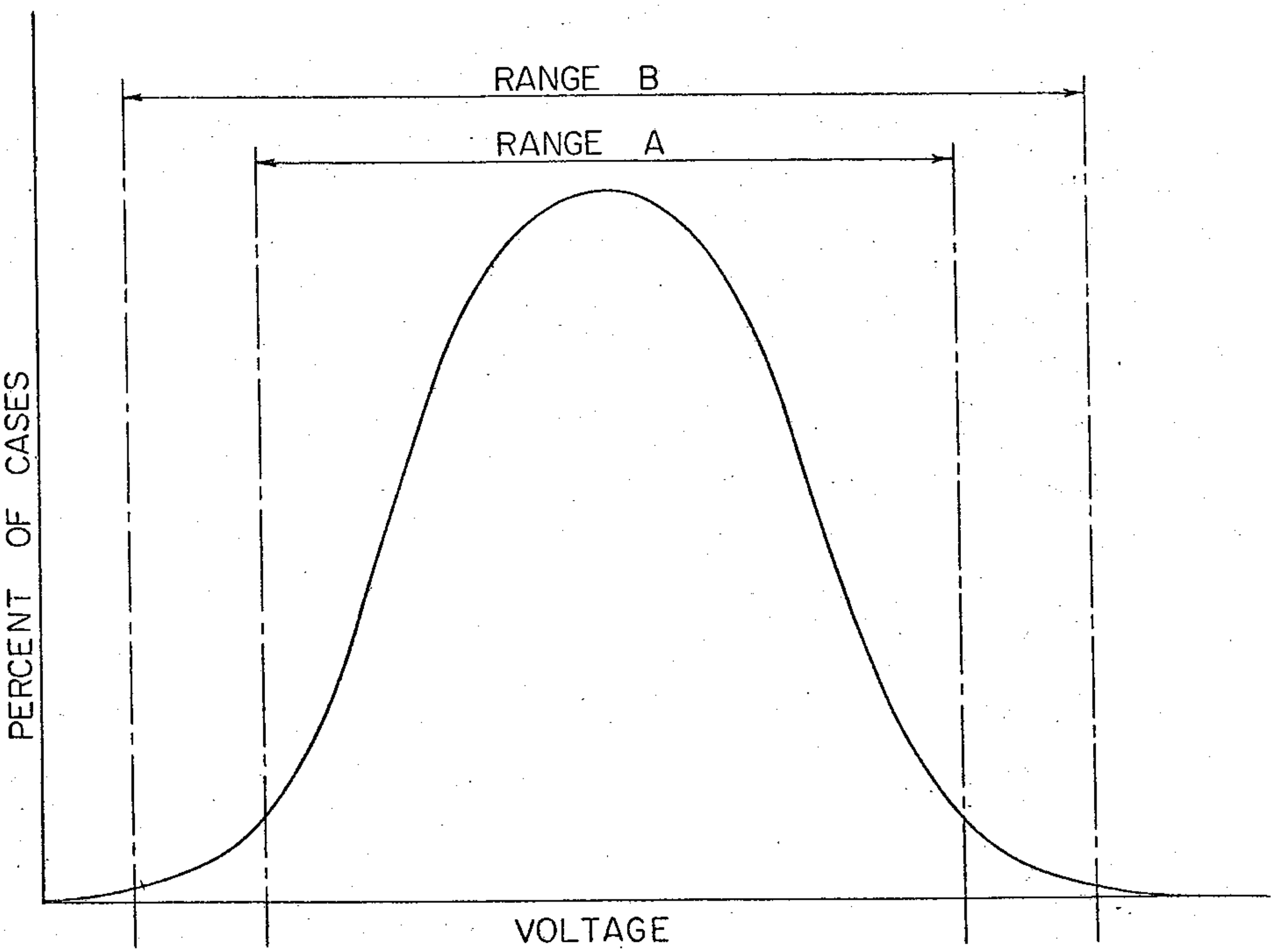

FIG. 1

DISTRIBUTION CHARACTERISTICS OF
SYSTEM VOLTAGES

Table C2

Heating, Refrigeration, and Air-Conditioning Equipment

Equipment	Phase	Applicable to All Nominal System Voltages Containing This Voltage(s)	Equipment Nameplate Voltage Rating
Gas and oil furnaces and fractional hp fan coil units	1	120	115
		240	230
Stokers	1	120	115
Refrigerators & freezers	1	120	115
Room air conditioners	1	120	115
		208	208, (200)*
		240	230
		208, 240	208/230†, (200/230)*†
Unitary air conditioners and heat pumps Motor-compressors Condensing units Water-chilling packages Integral hp fan coil units, etc Duct and auxiliary electric heaters for air-conditioning units and heat pumps	1&3	208	208, (200)*
	1&3	240	230
	1&3	208, 240	208/230†, (200/230)*†
	1	277	265
	3	480	460
	3	600	575
Electric furnaces	1&3	240	230
	3	208	208, (200)*
Comfort heating	1	120	120, (115)*
		208	208, (200)*
		240	240, (230)*
		277	277, (265)*
Refrigerated drinking water coolers	1	120	115
Dehumidifiers	1	120	115

*Parenthetical values are under consideration for future design.
†Slant between voltage values denotes "either, or".