UNITED STATES DEPARTMENT OF AGRICULTURE
RURAL ELECTRIFICATION ADMINISTRATION
WASHINGTON, D.C. 20250

November 1970

*Reviewed & Approved*
*For Reprinting 4/82*

*SUBJECT:* Revision of REA Bulletin 169-4, "Voltage Levels on Rural Distribution Systems"

*TO:* All Electric Borrowers

A revised American National Standard, C84.1-1970, "Voltage Ratings for Electric Power Systems and Equipment (60 Hertz)," has been approved by the American National Standards Institute. This standard establishes ranges of service and utilization voltages which are somewhat more restrictive than those of the previous standard C84.1-1954 . We expect the new standard will eventually be adopted or used as a guide by regulatory authorities in many states.

Borrowers and their engineers should, insofar as possible, comply with the requirements of C84.1-1970. This revised bulletin includes recommendations of voltage ranges for the various portions of the distribution system. Observance of these recommendations generally will not require any major revision of system plans or large expenditure for those borrowers who have followed recommendations in the previous bulletin.

This bulletin supersedes REA Bulletin 169-4, "Voltage Levels on Rural Distribution Systems," dated March 1952.

JAMES N. MYERS
Assistant Administrator - Electric

TABLE OF CONTENTS

Voltage Levels
on
Rural Distribution Systems

UNITED STATES DEPARTMENT OF AGRICULTURE
Rural Electrification Administration

November 1970

# REA BULLETIN 169-4

SUBJECT: Voltage Levels on Rural Distribution Systems

I. Purpose: The purpose of this bulletin is to recommend voltage levels and voltage limits to serve as guidelines in the general design and operation of rural electric distribution systems.

II. Voltage Standards: The recent American National Standards Institute (ANSI) Publication ANS C84.1-1970, "Voltage Ratings for Electric Power Systems and Equipment (60 Hertz)," (1) establishes standards on voltage limits for the electric distribution supply system. It includes voltage limits within which utilization equipment should operate satisfactorily. It thus serves as a guideline for the electrical manufacturer in equipment design and for the user in designing his electrical wiring system. The recommendations in this bulletin are based on this ANSI voltage standard.

III. American National Standard:

A. Definitions

The American Standards Institute voltage standard ANS C84.1-1970 defines "Range A" and "Range B" voltage limits as follows:

1. Range A

- Service Voltage

  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.

- Utilization Voltage

  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 so designed and rated to give fully satisfactory performance throughout this range.

2. Range B

- Service and Utilization Voltages

This range includes voltages above and below Range A limits that necessarily result from practical design and operating conditions on supply and/or user systems. 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 performances in the extremes of this range of utilization voltage, although not necessarily as good performance as in Range A.

B. Voltage Limit Values

The voltage limits of Range A and Range B refer to utilization and service voltages. The effects of these limits on primary distribution voltages are discussed later in this bulletin.

Table 1. Voltage Ranges (120-volt base)

| Range | MINIMUM | | | MAXIMUM |
|---|---|---|---|---|
| | Utilization Voltage* | | Service voltage | Utilization & service voltage |
| | Non-lighting loads | Loads including lighting | | |
| A | 108 | 110 | 114 | 126 |
| B | 104 | 106 | 110 | 127 |

*Note: Caution should be exercised in using minimum utilization voltages as in some cases they may not be satisfactory for the equipment served. For example, where existing 220-volt motors are used on 208-volt circuits, the minimum utilization voltage permitted would not be adequate for operation of the motors.

## IV. REA Recommendations on Voltage Levels

### A. Basic Design Criteria

1. Rural electric distribution systems should be designed and operated to meet the voltage level requirements of "Range A" in ANS C84.1-1970. Users' utilization electrical equipment of all types will generally be designed to give satisfactory performance in this range.

2. It is recognized that maintaining voltage levels within "Range A" on all parts of the system at all times cannot be assured. Due to the economics of operation, there may be some system voltages that fall in the extremes of "Range B" and even beyond. This may occasionally occur as the feeder reaches its design loading limit at annual or semi-annual peak loads.

3. When voltages frequently extend into "Range B," they should be corrected to conform to "Range A" requirements within a reasonable time. If voltages on any part of the system fall outside the limits of "Range B," corrective action should be taken to bring these voltages within "Range B" requirements immediately, and within "Range A" requirements within a reasonable time.

   Some types of utilization equipment will not perform satisfactorily or efficiently at the extremes of "Range B" voltages. Outside "Range B" voltage limits, many types of utilization equipment may fail to operate and may be seriously damaged or suffer shortened operating life. Voltages above the limits of "Range B" may be especially damaging to the users' utilization equipment.

### B. Basic Operating Conditions

For convenience, voltage values and voltage drops in this discussion are reduced to a 120-volt base. For example, the system nominal single phase primary voltage of 7200 volts has been divided by the ratio 60:1 to give 120 volts as a base for expressing voltage values and voltage drops.

Voltage level and limit values are based on the following:

- The outgoing substation voltage is regulated by a suitable voltage regulator.

- The regulator voltage band width setting does not exceed two volts on a 120-volt base.

- Voltage values used are at the center of the voltage regulator band width.

- All voltage regulators, whether at the substation or out on the line, have properly set and functioning line drop compensators.

- Only sustained voltages apply to these levels and limits. The flicker and variations caused by motor starting, equipment switching, variation of voltage within the voltage regulator band width, and similar short duration variations are not considered.

C. Power Input to Distribution Substations

The voltage of the power input to distribution substations should be kept within limits such that:

- Voltages are kept within the design limits of the substation transformers and other equipment.

- The substation voltage regulator can maintain the voltages on its output bus within the limits given in this bulletin.

D. Primary Distribution Voltages

1. The maximum permissible voltage drop on the primary of any electric distribution feeder is eight volts. This will normally occur at the time of annual peak load. At this maximum load the voltage drop is measured or calculated from the regulated substation bus to the primary terminals of the distribution transformer at the end of the line. The end of the line would be the end of the feeder, or any branch of the feeder, whichever results in the greatest voltage drop.

2. The maximum permissible voltage at the regulated substation bus is 126 volts. Therefore, at the maximum drop of eight volts on the primary, the minimum voltage at the primary terminals of any distribution transformer on the feeder or any of its branches would be 118 volts.

E. Distribution Transformer and Services

1. The minimum voltage at the primary terminals of any distribution transformer is 118 volts, and the maximum is 126 volts. This gives a spread of eight volts, but with a properly set and functioning line drop compensator, this spread can be reduced to about four volts. The minimum

service voltage (at the consumer meter or entrance switch) is 114 volts, and the maximum is 126 volts, a spread or swing of 12 volts. The line drop compensator of the voltage regulator, if properly set, would reduce this swing to about eight volts.

2. The voltage drop through the transformer and service conductors to the consumers' service (meter or entrance switch) should be limited to four volts at maximum design load on the service.

3. At points nearer the substation more latitude in transformer-service conductor voltage drop is possible. This is accomplished by recognizing that the full primary voltage drop of eight volts does not occur close-in to the substation. Under these conditions, the transformer-service conductor voltage drop may be increased to a maximum of six volts.

F. Consumer Utilization Voltages

With a recommended service voltage of 114 volts and a recommended minimum utilization voltage of 110 volts, this provides for a four-volt drop in the consumer's wiring system. The 110-volt minimum and 126-volt maximum utilization voltage gives a voltage spread of 16 volts, which can be reduced to about 12 volts with a properly functioning line drop compensator on the voltage regulator.

Table 2. Voltage Drops for Rural Electric Distribution System Design (120-volt base)

| | Maximum Volts Drop | Percent Volts Drop |
|---|---|---|
| Substation regulated bus (output) to last distribution transformer (primary) | 8 | 6.67 |
| Distribution transformer (primary) to service delivery connection to consumers' wiring (meter or entrance switch) | 4 | 3.33 |
| Utility service delivery point (meter or entrance switch) to consumers' utilization terminal (outlet): | | |
| Loads including lighting | 4 | 3.33 |
| Nonlighting loads | 6 | 5.00 |

Table 3. Voltage Level Limits and Spread for Rural Electric Distribution Systems. (Measured at center of regulator bandwidth - 120 volt base).

| | Voltage Levels (volts) | | Voltage Spread (volts) |
|---|---|---|---|
| | Minimum | Maximum | |
| Substation Regulated Bus with Regulator Line Drop Compensator in Use | 122 | 126 | 4 |
| Distribution Transformer Primary Terminals: | | | |
| At end of line (8-volt drop) | 118 | 122 | 4 |
| Adjacent to substation bus | 122 | 126 | 4 |
| Service Connection to Consumer Wiring: | | | |
| At end of line (8-volt drop on primary) | 114 | 122 | 8 |
| At transformer nearest substation bus | 118 | 126 | 8 |
| Point of Consumer Utilization: | | | |
| At 8-volt drop on primary (Lighting loads) | 110 | 122 | 12 |
| (Nonlighting loads) | 108 | 122 | 14 |
| At transformer nearest to substation bus (Lighting in load) | 112 | 126 | 14 |
| At transformer nearest to substation bus (Nonlighting load) | 108 | 126 | 18 |

## DEFINITIONS OF TERMS*

A glossary of terms is listed to facilitate understanding of the subject matter of this bulletin.

### Band Width

The band width of a voltage regulator is the voltage spread within which the regulator will hold the output voltage. This does not include a change in output voltage brought about by the application of line drop compensation.

### Base Voltage

Base voltage is a reference value which is a common denominator to the nominal voltage ratings of transmission and distribution lines, transmission and distribution equipment, and utilization equipment. For example, the base voltage of a transmission line having a nominal voltage rating of 34,500 volts is 115 volts; and the base voltage of a distribution line having a nominal voltage rating of 7,200 volts is 120 volts. In general, distribution lines and associated equipment having a nominal rating of from 2400 volts through 19,920 volts will have a 120-volt base, and the nominal voltage rating of utilization equipment served by these voltages will also have a 120-volt base.

### Equipment

The term "equipment" is the general term and includes material, fittings, devices, appliances, fixtures, apparatus, and the like, used as part of, or in connection with, an electrical installation.(2)

### Equipment Operating Voltage Spread

Equipment operating voltage spread is the spread between the minimum and maximum voltages within which the equipment will operate and meet performance specifications.

### Maximum Voltage

Maximum voltage is the greatest sustained mean or average voltage.

### Minimum Voltage

Minimum voltage is the least sustained mean or average voltage.

* Numbers in parentheses refer to references listed.

Nominal Voltage

The nominal voltage of a circuit or system is a nominal value assigned to the circuit or system for the purpose of conveniently designating its voltage class.(1) For example, the nominal rural residential voltage is 120 volts, although the voltage may actually range from 114 volts to 126 volts.

Service Voltage

Service voltage is the voltage at the point where the electric systems of the supplier and the user are connected.(1) In rural systems this is usually considered the voltage at the meter socket or entrance switch.

Voltage Regulator

Voltage regulator is a device consisting of a regulating transformer and means for adjusting the voltage of the circuit without interrupting the load.

Utilization Voltage

Utilization voltage is the voltage at the line terminals of utilization equipment.(1) This is generally considered to be the voltage at the terminals of the device or appliance or the voltage at the convenience outlet to which these terminals are connected.

Voltage Drop

Voltage drop (in a supply system) is the difference between the voltages at the transmitting and receiving ends of a feeder, main or service.

Voltage Level

Voltage level is a generalized term that is synonymous with mean voltage or average voltage. The period of time involved is usually of short duration, such as, for example, five minutes.

Voltage Spread

Voltage spread is the range of voltages which lies between the maximum and minimum voltages.

## References

1. ANS C84.1 - 1970, Voltage Ratings for Electric Power Systems and Equipment (60 Hertz), issued 1970.

2. ANS C84.1 - 1954, Preferred Voltage Ratings for A-C Systems and Equipment, issued 1954.

3. Utilization Voltage Standardization Recommendations, October 1942, EEI Publication No. J8.

4. REA Bulletin 169-27, Voltage Regulator Application on Rural Distribution Systems; 1954, with Supplement of November 29, 1963.

Copies of the newly published American National Standard Voltage Ratings for Electrical Power Systems and Equipment (60 Hz), C84.1-1970 are available from ANSI at $4.00 a copy.

Address request to:

American National Standards Institute, Inc.
1430 Broadway
New York, New York 10018