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Power Supply Guidelines for X-ray Machines

NEMA

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION ■ 2101 L STREET, N.W., WASHINGTON, D.C. 20037

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Power Supply Guidelines for X-ray Machines

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Section 1
REFERENCED STANDARDS

In this publication reference is made to the standards listed below. Copies are available from the indicated sources.

American National Standards Institute
11 W. 42nd Street
New York, NY 10036

ANSI C84.1-1989 — *Power Systems Voltage Ratings for Electric Equipment (60 Hz)*

NEMA/IEC 601-1987 — *Medical Electrical Equipment—Part 1, General Requirements for Safety*

National Fire Protection Association
Publications Sales Department
Batterymarch Park
Quincy, MA 02269

NFPA 70-1990* — *National Electrical Code*

*Also available from American National Standards Institute

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POWER SUPPLY GUIDELINES FOR X-RAY EQUIPMENT

(Authorized Engineering Information 1-11-1983)

Section 2
EQUIPMENT TYPES

2.1 SELF-RECTIFIED

Self-rectified X-ray equipment include most dental equipment and lower powered medical equipment used for radiography and fluoroscopy. This equipment may be portable, mobile, or stationary.

2.2 SINGLE-PHASE FULL-WAVE

Single-phase full-wave X-ray equipment may be used for radiography and fluoroscopy and is usually permanently installed in small departments or private offices. Some equipment of this class is also used in portable and mobile applications.

2.3 THREE-PHASE PRIMARY-CONDUCTING

Three-phase primary-contacting X-ray equipment is used in both general and special procedure radiographic, fluoroscopic, and computed tomography (CT) system installations in hospitals.

Authorized Engineering Information 8-28-1991.

2.4 THREE-PHASE SECONDARY-CONTACTING

Three-phase secondary-contacting X-ray equipment is used in some special procedure departments for radiography, fluoroscopy, and CT systems. Since the high-voltage switching tubes also regulate kV output, the input power requirements are higher than for primary-contacting machines because of the power dissipated in the tubes.

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Section 3
GENERAL

3.1 Select the classification under the rated output columns in Table 3-1. If only the mA is known, or for kVp's less than 100 kVp (as with dental and low-powered units), use the mA value under the 100 kVp heading. For values between the listed values, use the next highest value.

3.2 The listed specifications in Table 3-1 are for typical minimum requirements for a single generator of the specified ratings and are intended only for preliminary cost estimating. Final power supply requirements should be based on the recommendations of the manufacturer of the X-ray equipment.

3.3 Three-phase X-ray equipment frequently requires "Wye"-connected balanced-to-ground outputs from the distribution transformer. This is particularly true of European designed or manufactured X-ray equipment.

3.4 The distribution transformer and feeder/branch circuit wire sizes are designed for not more than 3 percent voltage regulation at the design capacity of the distribution transformer and not more than 5 percent under the X-ray equipment load. The X-ray equipment kVA load is frequently 50 to 75 percent higher than the listed nominal kW output. Final power supply requirements should be based on the recommendations of the manufacturer of X-ray equipment.

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3.5 If more than one X-ray machine is to be connected, the capacity of the distribution transformer is usually determined from the requirements of the two largest units plus 20 percent of that for each additional unit. Example: an X-ray department plans to include six X-ray units (commonly called X-ray generators), one of which requires a 150-kVA distribution transformer and each of the others 112.5-kVA distribution transformers. The two largest X-ray units require 150 + 112.5 = 262.5 kVA. The remaining four X-ray units require 4 × 112.5 × 20% = 90 kVA. The total supply capacity required for the six machines would be 262.5 + 90 = 352.5 kVA.

3.6 The wire sizes listed in Table 3-1 are for single installations. Sizes listed under the 50-foot run are the minimum (within the limits of standard available sizes) permitted by Article 517-73(a)(1) of the *National Electrical Code*. For wire runs not listed in the table, increase the wire size to yield the same overall resistance as that of the sizes in the table. If the supply line voltage is less than the listed nominal voltage, use the next larger wire size. All listed wire sizes assume copper wire. Disconnect means rated at 100 amperes or less require 60°C conductors; all others require 75°C conductors.

3.7 For feeders and overcurrent protective devices supplying two or more X-ray machines, the approximate momentary demand (current) rating may be calculated from the kVA rating of the distribution transformer listed in the table for each X-ray machine and the actual line supply voltage. The minimum feeder wire size and overcurrent device rating (see Article 517-73(a)(2) of the *National Electrical Code*) is based on 50 percent of this rating for the two largest X-ray units plus 20 percent of the rating of each additional unit. This minimum permitted wire size is satisfactory for feeders not exceeding 50 feet in length. For longer lengths, increase the wire size to yield the same overall resistance.

CAUTION: For final design, use the manufacturer's stated momentary current for these calculations. The actual momentary kVA rating for a particular generator may be higher or lower than that of the recommended distribution transformer.

3.8 Special caution should be used when sizing parameters for bi-plane installations. If the two X-ray units are designed to make simultaneous (as opposed to alternating) multiple exposures with rapid film changers, both units must be considered as one unit. The load for the capacity of the distribution transformer and sizing feeders must be 100 percent of the value for each X-ray unit.

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3.9 The maximum allowable momentary line voltage variation due to causes other than the X-ray equipment load should not exceed + /- 2-1/2 percent. Caution should be taken when powering X-ray equipment from the same distribution source as elevators, heating, venting and air-conditioning (HVAC) and other phase controlled loads because of potential adverse effects on the operation of the X-ray equipment. The waveform of the supply should be practically sinusoidal with less than 5 percent (3 percent for CT) total harmonic distortion and less than 1 percent frequency variation. Signals from devices that use the power line as a means of distribution can be the source of problems and efforts should be undertaken to minimize such effects.

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3.10 Dental and mobile units requiring 1.5-kVA supply may be used on any Class A (ANSI C84.1) line.

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Table 3-1
Power Supply Guidelines for X-Ray Equipment♦
See Figure 3-1

Classification	Rated Output mA @ 50 kVp	mA @ 100 kVp	mA @ 125 kVp	mA @ 150 kVp	kW (Nominal)	Nominal Line Voltage	Recommended Supply Transformer Capacity-kVA	Typical Wire Size (AWG) Supply Transformer to Disconnect Switch 50 ft	100 ft	200 ft	Typical Wire Size (AWG) From Disconnect Switch to X-Ray Control, for Run of 15 ft.	Grounding Wire Size (AWG)	X-ray Disconnect Means Alternate 1 Switch & Fuse Switch Rating Amp	Fuse Rating Amp	Alternate 2 Circuit Breaker Rating Amp
Self-rectified		15			1.2	120	1.5	12	10	8	12	12	30	20	20
X-Ray		30			2.3	120	5.0	8	6	3	10	10	30	30	30
Machines		15			1.2	240	1.5	14	12	10	12	14	30	15	15
		20			1.6	240	5.0	14	12	10	14	14	30	15	15
		30			2.3	240	5.0	10	8	6	14	14	30	15	15
		60			4.7	240	10.0	8	6	3	8	10	60	50	50
		100			7.8	240	15.0	4	2	00	8	10	60	60	60
Single-phase,		50			4	240	3.0	6	4	1	10	10	30	30	30
Full-wave X-ray		100	75		8	240	7.5	8	6	2	10	10	60	40	40
Machines		200	150	125	16	240	15.0	4	2	00	8	10	60	60	60
		300	200	175	20	240	25.0	4	2	00	6	10	60	60	60
		500	400	300	40	240	37.5	2	00	250kcmil	2	8	100	100	100
		750	600	500	60	240	50.0	0	0000	350kcmil	0	6	200	150	150
		1000	800	600	80	480	75.0	2	00	250kcmil	2	6	100	100	100
Three-phase		500	400	300	50	208	45.0	3	0	0000	2	8	100	90	90
Primary-		700	600	500	75	208	75.0	1	0	0000	0	6	200	125	125
contacting		1000	800	600	100	208	112.5	00	000	300kcmil	00	6	200	175	175
X-ray Machines		700	600	500	75	480	75.0	4	4	1	4	8	100	70	70
		1000	800	600	100	480	112.5	3	3	0	4	8	100	90	90
		1500	1200	1000	150	480	150.0	1	0	0000	2	6	200	125	125
Three-phase		700	500	400	70	480	150.0	1	000	300kcmil	2	6	200	125	125
Secondary-		1000	800	600	100	480	200.0	00	0000	400kcmil	0	6	200	175	175
contacting		2200	1500	600	220	480	480.0	350MCM	350MCM	600kcmil	0	4	400	300	300
X-ray Machines															
CT System	30 kVA per room					208	45	2	00	300kcmil	2	2	100	100	100
three-phase	regardless of technique					480	75	6	4	0	4	*	100	80	80
inverter type	factors														

♦ National Electrical Code, Article 517-73(a) (2), fine print note: "The minimum conductor size for branch and feeder circuits is also governed by voltage regulation requirements. For a specific installation, the manufacturer usually specifies: minimum distribution transformer and conductor sizes, rating of disconnect means, and overcurrent protection."

*Grounding wire size is the same as the typical wire size from supply transformer to disconnect switch.

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NOTE: Total impedance not to exceed specified value from equipment specifications.

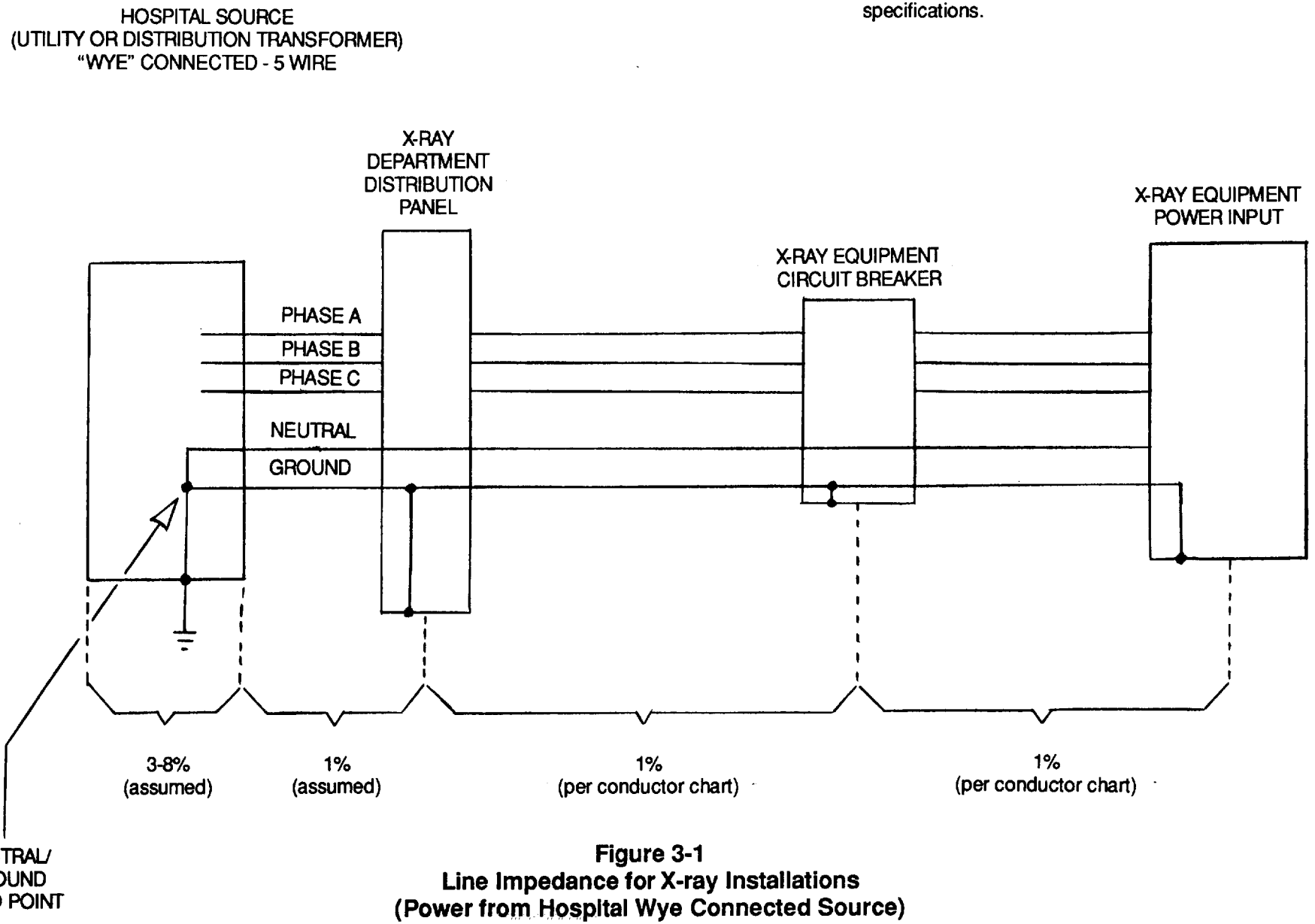

Figure 3-1
Line Impedance for X-ray Installations
(Power from Hospital Wye Connected Source)

Suitable wall receptacles rated at least 15 amperes for a 1.5-kVA supply and 20 amperes for a 5-kVA recommended supply may be used. Time lag fuses are often utilized.

3.11 X-ray machine accessories vary too greatly to be separately listed and in many cases are operated from the same supply as the X-ray machine without overloading that supply. Examples are:

(1) X-ray tube stator supply — single-phase 120 volts, 0.5 kVA; to three-phase 480 volts, 5 kVA.

(2) Table tilt drive — single-phase 120 volts, 1.5 kVA; to three-phase 480 volts, 15 kVA.

(3) Other accessories — single-phase 120 volts to three-phase 480 volts, 1.5 kVA or less.

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Section 4
DEFINITIONS

4.1 CLEAN LINE

- Less than 3 percent distortion
- No line carried radio frequency (RF) from diathermy, diagnostic, or other equipment.
- No line disturbances from "load dumping" such as elevators, or line step sags such as from X-ray units.
- Line is dedicated to the CT suite from the distribution transformer.
- No common breaker/fuse with another room/equipment.
- Ground is isolated, dedicated to CT room, parity sized with line conductors from distribution/generation regulation source.
- Ground is drawn with source wires.

4.2 VOLTAGE SAG/SURGE

- Any variation in nominal line voltage occurring in less than three line cycles and continuing up to several seconds.
- (Switchover of supply may cause loss of scan and/or equipment damage. Less than 2 milliseconds may suffice.)

4.3 CT GENERATOR

- A high voltage X-ray power supply with output quality as required for a specific type of CT scanner use.

4.4 MOBILE POWER

- Power source for mobile equipment, either at site or carried with equipment.

4.5 MOTOR GENERATORS

- A motor driven generator sourced by the site power.

4.6 SHORE POWER CALIBRATION

- Same as normal equipment needs.

4.7 LINE IMPEDANCE VERSUS REGULATION

$$Z\ \text{line} = \frac{VNL - VFL}{IFL}$$

$$\frac{VNL - VFL}{VFL} \times 100 = \%\ \text{regulation}$$

where:

Z = line impedance
VNL = no load voltage
VFL = full load voltage
IFL = full load current

- Line impedance should be established at the lowest incoming line voltage, using a maximum kVA load and correcting for -10% possible measurement error (as cited in IEC 601-2-7, p. 21).

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NEMA STANDARDIZATION

The purpose of NEMA Standards, their classification and status are set forth in certain clauses of the NEMA *Standardization Policies and Procedures* manual and are referenced below:

Purpose of Standards

National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for their particular needs. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard.

(Standardization Policies and Procedures, p. 1)

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process or procedure with reference to one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Standardization Policies and Procedures, p. 2)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the Standards Publication may be capable of otherwise equivalent performance.

(Standardization Policies and Procedures, p. 8)

Categories of Standards

National Electrical Manufacturers Association Standards are of three classes:

1. NEMA Standard, which relates to a product, process or procedure commercially standardized and subject to repetitive manufacture, which standard has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon;
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.
3. Adoptive Standard, which is adopted in whole or in part from the standards of another organization, either domestic, regional, or international.

(Standardization Policies and Procedures, pp 7 & 16)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote on the standard.

(Standardization Policies and Procedures, pp. 7 & 16)

Official Standards Proposal

An Official Standards Proposal is an official draft of a proposed standard which is formally recommended to an outside organization(s) for consideration, comment and/or approval, and which has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon. *(Standardization Policies and Procedures, pp 7 & 16)*

Identification of Status

Standards in NEMA Standards Publications are identified in the foreword or following each standard as "NEMA Standard" or "Suggested Standard for Future Design." These indicate the status of the standard. These words are followed by a date which indicates when the standard was adopted in its present form by the Association.

The material identified as "Authorized Engineering Information" and "Official Standards Proposal" is designated similarly.

July 17, 1990

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