Electrical Power Systems and EV Charging

Presented to Philadelphia Chapter of PSPE

By: **Joseph F. Maida, PE**

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1315 Walnut St #804
Philadelphia, PA 19107
P 215.542.8700 F 215.732.2070

Visit us online at
www.MaidaEng.com

Joseph F. Maida, P.E. *President*
Maida Engineering, Inc.

Qualifications:

- BSEE – Drexel University – 1971
- MSEE – Drexel University (Power) – 1976
- Licensed Electrical Contractor 1971 -1976
- Officer - US Army Reserve 1971 – 1979
- Delmarva Power & Light Co.1972 – 1974
- Day & Zimmermann, Inc. 1974 -1978
- Maida Engineering, Inc. – 1978 – Present
- PE License – PA -1975 (NJ, NY & DE 1976)
- PE License – ID, MA, NC, GA, FL, TX, IA, WV, AK, TN, MD, KS, MO, OH, VA, SC, NM, OR, LA, AL and MN
- LEED Accredited Professional - June 2009
- PA UCC Review and Advisory Council 2009 -2011
- Patent – Wind Tunnel Motor/Drive/Control - 2020

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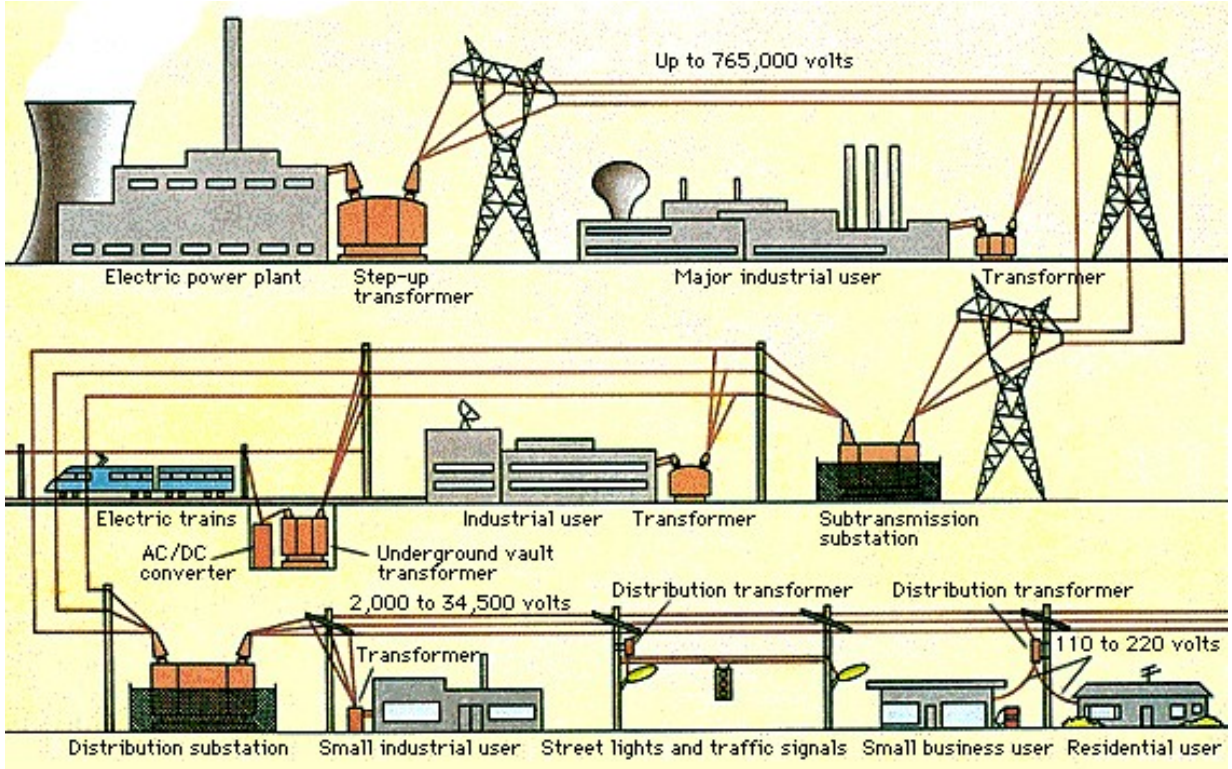
Electrical Power System

"Electric Power Systems"

provide AC utilization voltages to equipment within residential, commercial and industrial buildings and facilities.



Electrical Power System Basics

An "Electric Power System" is a "closed" system in which electrons or electricity flow.

A "Component" is a piece of electrical equipment, including a line or circuit or a section of a line or circuit, or an interconnected group of electrical equipment.

An "Electric Power System" is composed of the Generators, Transformers, Motors, Appliances, Power Electronics and Protective Devices that are designed to carry the flow of electricity within the system under normal conditions and when a short circuit occurs.

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Electrical Power System Basics

An "Electric Power System" has transmission and distribution circuits connected in network or radial distribution configuration that connect the AC power sources and the AC power loads.

Synchronous Generators create AC power at a frequency that is directly proportional to the speed at the generator's rotor.

Sybchronus Genrators must be synchronized to match voltage waveform they are connect to.

Induction (Asynchronous) Generators create AC power at the frequency of the system it is connected to.

What type of generator is coomonly used for emergency backup power?

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Electrical Power System Basics

Wind turbines create AC power and are mostly induction generators.

Photovoltaic cells, fuel cells, batteries and DC generators create DC Power.

Active Rectifier use IGBTs to convert DC power to AC at the AC supply power system's frequency. They also convert AC to DC to charge batteries.

Invertors are used to convert DC to AC power at a controlled frequency for VFDs and UPSs and Electric Vehicals

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Electrical Power System Basics

Electrical power system must be designed to return to their stable configuration, which occurs when synchronous generators are synchronized, after large disturbances.

Active Rectifies convert potential DC power to AC power to supply loads, whereas

AC Generators generate kinetic AC power to accommodate loads.

Electrical grids have all synchronous generators synchronized to maintain stability.

Smart grid technology increase electric grid reliability.

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Electrical Power System Basics

Adequately designed AC Electric Power Systems:

- **Will carry full load currents while maintaining the utilization voltage within a defined range**
- **Will selectively isolate portions of the power system when short circuits or overloads occur.**
- **Will carry short circuit and overload currents without damaging components until the section that is overloaded or has a short circuit is isolated.**

Electrical Power System Basics

Properly designed AC Electric Power Systems:

- **When applicable, must follow building and fire codes that include the National Electrical Code, NFPA 70 (NEC).**
- **Should comply with other life safety and fire codes and standards such as The Standard for Electrical Safety in the Workplace, NFPA 70E. (Does not apply to residences)**
- **Should comply with Insurance Company and other standards, such as FM and IEEE Recommended Practices**
- **Should comply with IEEE-519-2014, IEEE Recommended Practice and Requirements for Harmonic Control**

Electrical Power System Basics

National Electrical Code NFPA 70 - NEC®

- Updated every 3 years – NOT GRANDFATHERED.
- No court in the USA has faulted anyone for using the latest version of the NEC®, even when the local code was not updated.[1.]
- "Is not intended as a design specification or an instruction manual for untrained persons."
- Electric power system installations that are properly maintained should be essentially free from hazard.

1. http://en.wikipedia.org/wiki/National_Electrical_Code_(US)

Electrical Power System Basics

Power System Calculations

Electrical Power, P, measured in volt amperes, VA, is directly proportional to the electrical current measured in amperes, I, and the electrical voltage measured in volts, V.

Electrical Power can be measured in volt-amperes.

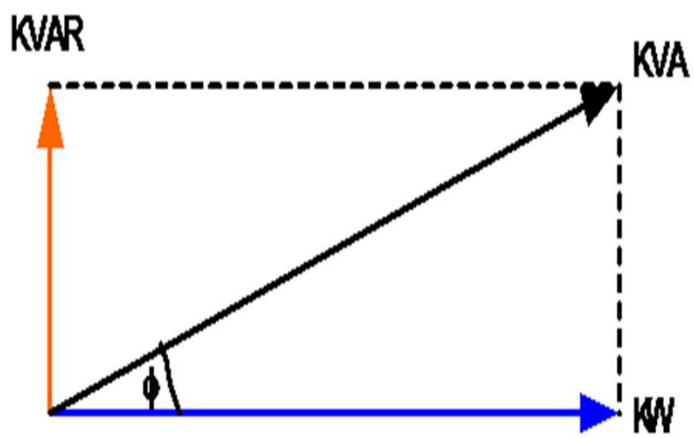
1 phase system: VA = V X I

3 phase system: VA = V X I X 1.732

1,000 VA = 1 KVA

KVA = KW ÷ POWER FACTOR

$KVA^2 = KW^2 + KVAR^2$



Electrical Power System Basics

AC System Impedance, Z, is a complex number composed of resistance, R, and Reactance, X.

$$Z^2 = R^2 + X^2$$

Complex Per Unit AC System Analysis, eliminates this assumption. Usually performed using computer software

DC System Resistance, R, is not a complex number.

Electrical Power System Basics

Ohm's Law

- The electrical current within a DC circuit, I, is directly proportional to the system voltage, V, and indirectly proportional to the system resistance, R.

$$I = V/R \quad \text{or} \quad V = I \times R$$

- The electrical current within an AC circuit, I, is directly proportional to the system voltage, V, and indirectly proportional to the system impedance, Z.

$$I = V/Z \quad \text{or} \quad V = I \times Z$$

- Resistances, reactances and Impedances for 3Ø, 60 Hz conductors in conduit are published in Table 9 in the NEC.

Electrical Power System in the USA

Electrical Service

- "The conductors and equipment connecting the service utility to the building or facility served.
- Typically, one but could be more for a building or facility.
- Sized based on a calculated load using various Articles in the legally adopted version of the NEC.
- Owned by the building or facility and unlike the utility must comply with the NEC.
- Can be low voltage (< 1,000 volts) or medium voltage (>1,000 volts).

Electrical Power System in the USA

Electrical Service

Power – **Power is based on the building or facility loads, which are determined based on Articles in the legally adopted version of the NEC.**

Voltage – **Low voltage are Single Phase (1Ø) – 240/120 Volt from utility owned transformer for houses, or 3Ø – 208/120 Volt, 480/277 Volt, 240 Volt high leg delta or 480 Volt from transformers for commercial buildings and complexes**

Electrical Power System in the USA

Voltage – Medium voltage, above 1,000 Volts, are Three Phase (3Ø) and are "voltage regulated" up to 34,500 volts.

Voltage – ANSI C84-1-2020 provides the voltage limits that should be provided by the utility companies at the electrical service. An excerpt from C84-1-1989 follows:

IAL OLTAGE	Nominal Utilization Voltage (Note ;)	VOLTAGE RANGE A (Note b)			VOLTAGE RANGE B (Note b)		
		Maximum	Minimum		Maximum	Minimum	
Four-wire	Two-wire Three-wire Four-wire	Utilization and Service Voltage (Note c)	Service Voltage	Utilization Voltage	Utilization and Service Voltage	Service Voltage	Utilization Voltage
480Y/277	460	504Y/291	456Y/263	440Y/254	508Y/293	440Y/254	424Y/245
12 470Y/7 200		13 090Y/7 560	12 160Y/7 020	(Note f)	13 200Y/7 620	11 850Y/6 840	(Note f)

Electrical Power System in the USA

Table 3-1—Standard nominal system voltages and voltage ranges

(Preferred system voltages in bold-face type)

VOLTAGE CLASS	NOMINAL SYSTEM VOLTAGE (Note a)			Nominal Utilization Voltage (Note j)	VOLTAGE RANGE A (Note b)			VOLTAGE RANGE B (Note b)		
					Maximum	Minimum		Maximum	Minimum	
	Two-wire	Three-wire	Four-wire	Two-wire Three-wire Four-wire	Utilization and Service Voltage (Note c)	Service Voltage	Utilization Voltage	Utilization and Service Voltage	Service Voltage	Utilization Voltage
Low Voltage (Note 1)						Single-Phase Systems				
	120			115	126	114	110	127	110	106
		120/240		**115/230**	**126/252**	**114/228**	**110/220**	**127/254**	**110/220**	**106/212**
						Three-Phase Systems				
			208Y/120 (Note d)	**200**	**218Y/126**	**197Y/114**	**191Y/110**	**220Y/127**	**191Y/110** (Note 2)	**184Y/106** (Note 2)
			240/120	**230/115**	**252/126**	**228/114**	**220/110**	**254/127**	**220/110**	**212/106**
		240		**230**	252	228	220	254	220	212
			480Y/277	**460**	**504Y/291**	**456Y/263**	**440Y/254**	**508Y/293**	**440Y/254**	**424Y/245**
		480		**460**	**504**	**456**	**440**	**508**	**440**	**424**
		600 (Note e)		**575**	630 (Note e)	570	550	635 (Note e)	550	530
Medium Voltage		2 400			2 520	2 340	2 160	2 540	2 280	2 080
			4 160Y/2 400		4 370/2 520	4 050Y/2 340	3 740Y/2 160	4 400Y/2 540	3 950Y/2 280	3 600/2 080
		4 160			**4 370**	**4 050**	**3 740**	**4 400**	**3 950**	**3 600**
		4 800			5 040	4 680	4 320	5 080	4 560	4 160
		6 900			7 240	6 730	6 210	7 260	6 560	5 940
			8 320Y/4 800		8 730Y/5 040	8 110Y/4 680		8 800Y/5 080	7 900Y/4 560	
			12 000Y/6 930		12 600Y/7 270	11 700Y/6 760		12 700Y/7 330	11 400Y/6 580	
			12 470Y/7 200		**13 090Y/7 560**	**12 160Y/7 020**	(Note f)	**13 200Y/7 620**	**11 850Y/6 840**	(Note f)
			13 200Y/7 620		**13 860Y/8 000**	**12 870Y/7 430**		**13 970Y/8 070**	**12 504Y/7 240**	
			13 800Y/7 970		14 490Y/8 370	13 460Y/7 770		14 520Y/8 380	13 110Y/7 570	
		13 800			**14 490**	**13 460**	**12 420**	**14 520**	**13 110**	**11 880**
			20 780Y/12 000		21 820Y/12 600	20 260Y/11 700		22 000Y/12 700	19 740Y/11 400	
			22 860Y/13 200		24 000Y/13 860	22 290Y/12 870		24 200Y/13 970	21 720Y/12 540	
		23 000			24 150	22 430	(Note f)	24 340	21 850	(Note f)
			24 940Y/14 400		**26 190Y/15 120**	**24 320Y/14 040**		**26 400Y/15 240**	**23 690Y/13 680**	
			34 500Y/19 920		**36 230Y/20 920**	**33 640Y/19 420**		**36 510Y/21 080**	**32 780Y/18 930**	
		34 500			36 230	33 640		36 510	32 780	
		46 000			Maximum Voltage (Note g) 43 300					
		69 000			**72 500**					
High Voltage		**115 000**			**121 000**					
		138 000			**145 000**					
		161 000			163 000					
		230 000			**242 000**					
		(Note h)								
Extra-High Voltage		**345 000**			**362 000**					
		500 000			**550 000**					
		765 000			**800 000**					
Ultra-High Voltage		**1 100 000**			**1 200 000**					

NOTES: (1) Minimum utilization voltages for 120-600 volt circuits not supplying lighting loads are as follows.

Nominal System Voltage	Range A	Range B
120	108	104
120/240	**108/216**	**104/208**
(Note 2) **208Y/120**	**187Y/108**	**180Y/104**
240/120	**216/108**	**208/104**
240	216	208
480Y/277	**432Y/249**	**416Y/240**
480	**432**	**416**
600	540	520

(2) Many 220 volt motors were applied on existing 208 volt systems on the assumption that the utilization voltage would not be less than 187 volts. Caution should be exercised in applying the Range B minimum voltages of Table 1 and Note (1) to existing 208 volt systems supplying such motors.

Source: ANSI C84.1-1989

Copied from IEEE Red Book -

Electrical Power System in the USA

Electrical Service

Current (I) – Calculated using:

$$I = VA / V \text{ for } 1Ø \quad \text{or} \quad I = VA / (V \times 1.732) \text{ for } 3Ø$$

Current (Isc) – From utility or calculated using utility transformer:

$$KVA_{SC} = \frac{KVA_{nameplate}}{Z_{nameplate}} \qquad I_{SC} = \frac{KVA_{SC} \times 1000}{KV \times 1.732}$$

Electrical Power System Basic

The National Electrical Code (NEC) provides standard conductor properties and a method for calculating voltage drop using the following:

Vd = (2 x R x I x L)/1000 for DC systems

Vd = (1.73 x Z x I x L)/1000 for 3Ø systems

where:
Vd = voltage drop
Z = impedance of the conductor per 1000 ft.
R = resistance of the conductor per 1000 ft
I = load current in amperes
L = length in feet

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Electrical Power Systems NEC

The National Electrical Code (NEC) includes the following informational note:

Conductors for branch circuits as defined in Article 100, sized to prevent a voltage drop exceeding 3 percent at the farthest outlet of power, heating, and lighting loads, or combinations of such loads, and where the maximum total voltage drop on both feeders and branch circuits to the farthest outlet does not exceed 5 percent, provide reasonable efficiency of operation.

Voltage Drop Calculations

- ✓ For most residential installations, where the feeder or branch circuit length are 100 feet or less, voltage drop should not be an issue for circuit carrying loads that are 80% of the circuit conductor's ampacity.
- ✓ When in doubt go the following to calculate voltage drop:

https://www.southwire.com/calculator-vdrop

Electrical Power Systems NEC

ARTICLE 220 Branch-Circuit, Feeder, and Service Load Calculations

This article provides requirements for calculating branch-circuit, feeder, and service loads.

Part I Provides general requirements for calculation methods.

Part II Provides calculation methods for branch-circuit loads.

Parts III and IV Provide calculation methods for feeder and service loads.

Part V Provides calculation methods for farm load

Electrical Power System NEC

220.40 General. The calculated load of a feeder or service shall not be less than the sum of the loads on the branch circuits supplied,

- ✓ as determined by Part II of this article,
- ✓ after any applicable demand factors permitted by Part III or IV
- ✓ or required by Part V have been applied.

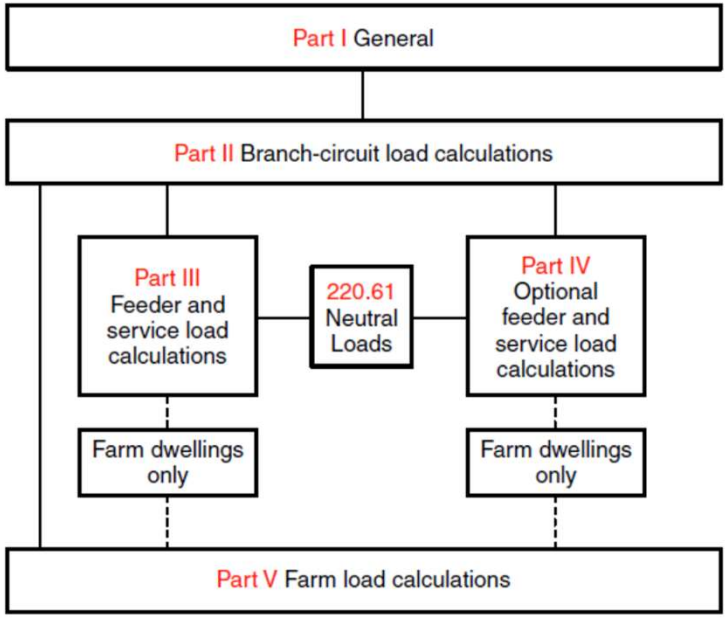


FIGURE 220.1 Branch-Circuit, Feeder, and Service Load Calculation Methods.

Electrical Power Systems NEC

Lighting Load for Specified Occupancies.

A unit load of not less than that specified in Table 220.12 for occupancies specified shall constitute the minimum lighting load. The floor area for each floor shall be calculated from the outside dimensions of the building, dwelling unit, or other area involved. For dwelling units, the calculated floor area shall not include open porches, garages, or unused or unfinished spaces not adaptable for future use.

Electrical Power Systems NEC

TABLE 220.12 *General Lighting Loads by Occupancy*

Type of Occupancy	Unit Load	
	Volt-amperes/m²	Volt-amperes/ft²
Armories and auditoriums	11	1
Banks	39[b]	3½[b]
Barber shops and beauty parlors	33	3
Churches	11	1
Clubs	22	2
Courtrooms	22	2
Dwelling units[a]	33	3
Garages — commercial (storage)	6	¼
Hospitals	22	2
Hotels and motels, including apartment houses without provision for cooking by tenants[a]	22	2
Industrial commercial (loft) buildings	22	2
Lodge rooms	17	1½
Office buildings	39[b]	3½[b]
Restaurants	22	2
Schools	33	3
Stores	33	3
Warehouses (storage)	3	¼
In any of the preceding occupancies except one-family dwellings and individual dwelling units of two-family and multifamily dwellings:		
Assembly halls and auditoriums	11	1
Halls, corridors, closets, stairways	6	½
Storage spaces	3	¼

[a]See 220.14(J).
[b]See 220.14(K).

NEC Table 220.12

Electrical Power System NEC

220.42 General Lighting.

The demand factors specified in Table 220.42 shall apply to that portion of the total branch circuit load calculated for general illumination.

Demand Factor shall not be applied in determining the number of branch circuits for general illumination.

TABLE 220.42 Lighting Load Demand Factors

Type of Occupancy	Portion of Lighting Load to Which Demand Factor Applies (Volt-Amperes)	Demand Factor (%)
Dwelling units	First 3000 at	100
	From 3001 to 120,000 at	35
	Remainder over 120,000 at	25
Hospitals*	First 50,000 or less at	40
	Remainder over 50,000 at	20
Hotels and motels, including apartment houses without provision for cooking by tenants*	First 20,000 or less at	50
	From 20,001 to 100,000 at	40
	Remainder over 100,000 at	30
Warehouses (storage)	First 12,500 or less at	100
	Remainder over 12,500 at	50
All others	Total volt-amperes	100

*The demand factors of this table shall not apply to the calculated load of feeders or services supplying areas in hospitals, hotels, and motels where the entire lighting is likely to be used at one time, as in operating rooms, ballrooms, or dining rooms.

Electrical Power System NEC

Dwelling Units – Branch Circuits Required

Small-Appliance Branch Circuits. In addition to the number of branch circuits required by other parts of this section, two or more 20-ampere small-appliance branch circuits shall be provided for all receptacle outlets specified by 210.52(B)

Laundry Branch Circuits. In addition to the number of branch circuits required by other parts of this section, at least one additional 20-ampere branch circuit shall be provided to supply the laundry receptacle outlet(s) required by 210.52(F). This circuit shall have no other outlets. *and (A)(2).*

Electrical Power System NEC

Dwelling Units – Branch Circuits Required

Bathroom Branch Circuits. In addition to the number of branch circuits required by other parts of this section, at least one 120-volt, 20-ampere branch circuit shall be provided to supply the bathroom(s) receptacle outlet(s). Such circuits shall have no other outlets.

Exception:* *Where the 20-ampere circuit supplies a single bathroom, outlets for other equipment within the same bathroom shall be permitted to be supplied in accordance with 210.23(A)(1) and (A)(2).

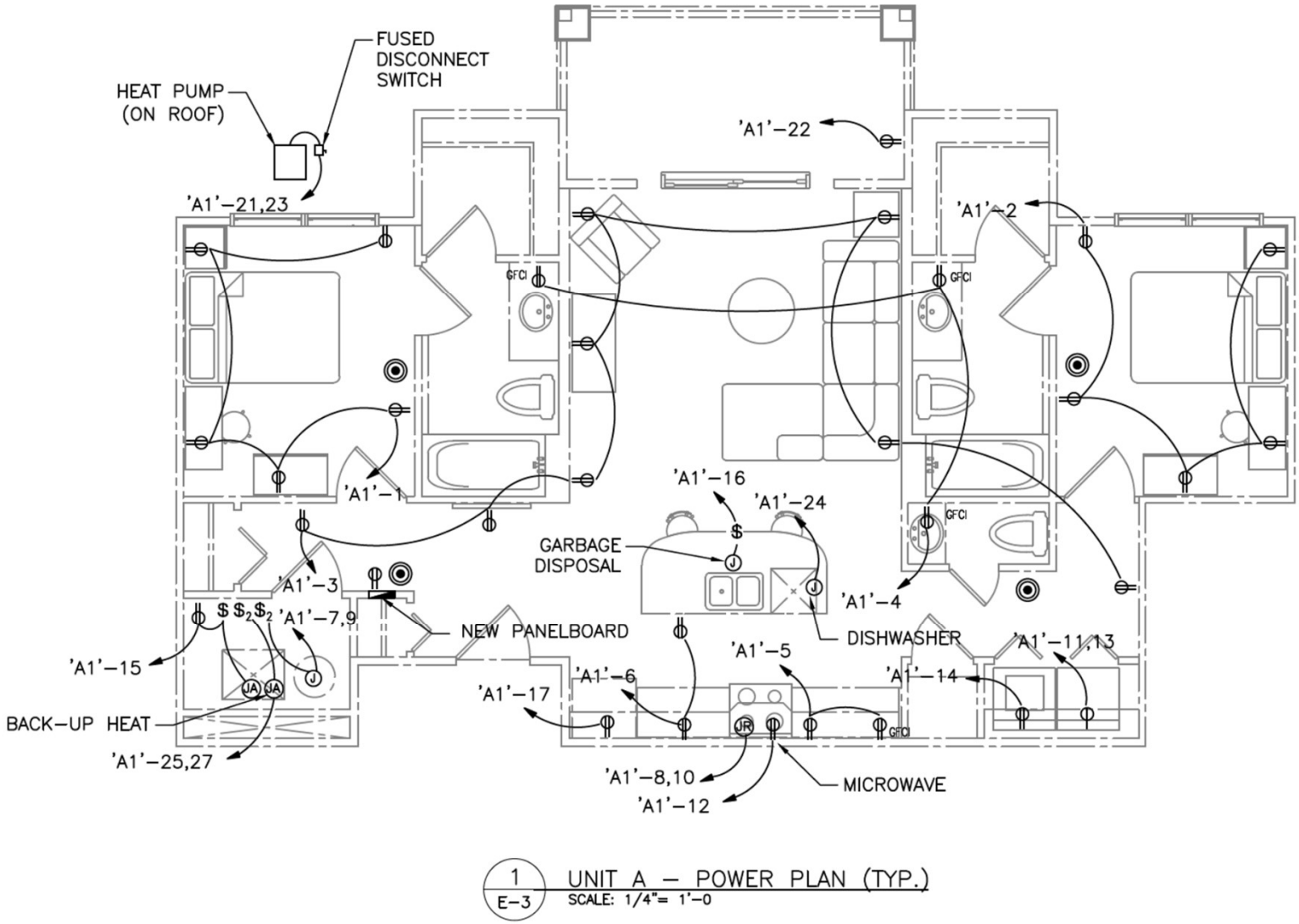
Electrical Power System NEC

Dwelling Units – Branch Circuits Required

Garage Branch Circuits: **In addition to the number of branch circuits required by other parts of this section, at least one 120-volt, 20-ampere branch circuit shall be installed to supply receptacle outlets in attached garages and in detached garages with electric power. This circuit shall have no other outlets.**

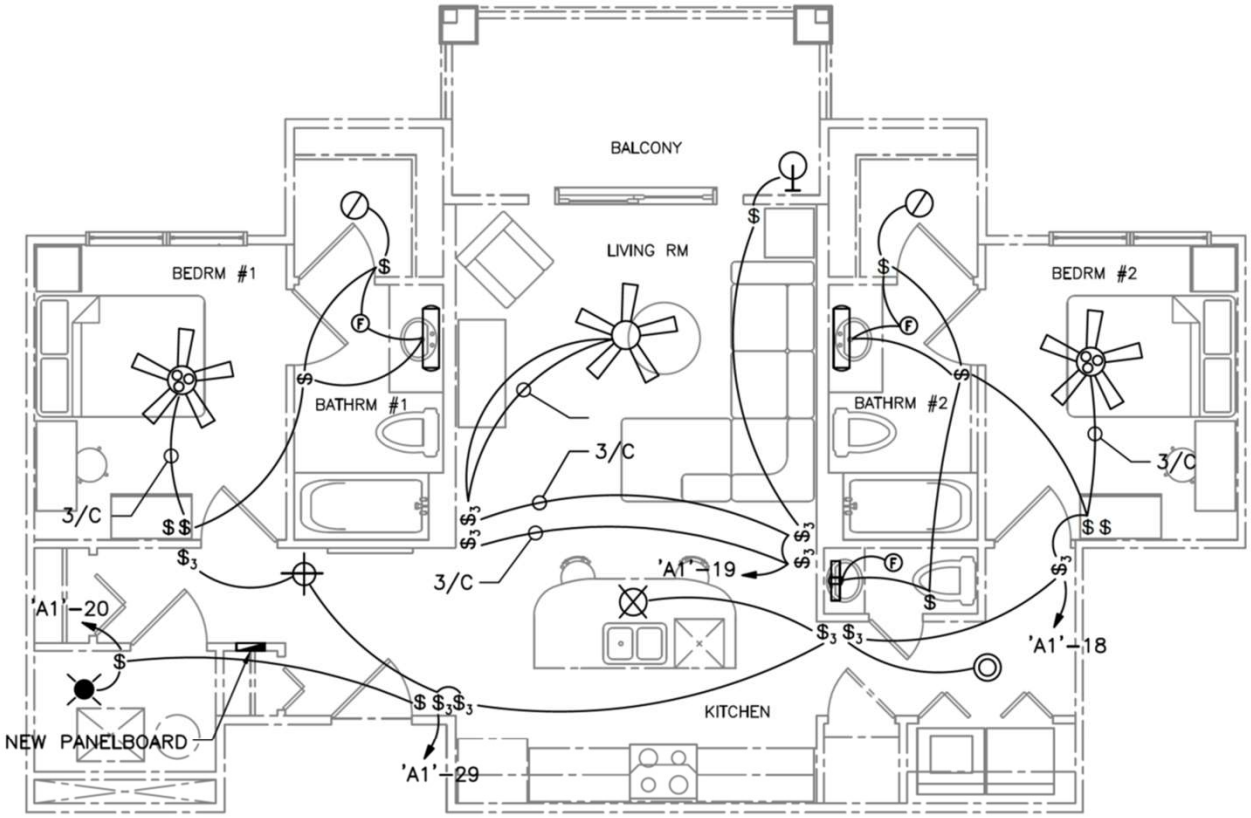
Exception: ***This circuit shall be permitted to supply readily accessible outdoor receptacle outlets.***

Student Apartment - 2013



1,414 SQUARE FOOT APARTMENT

Student Apartment - 2013



2 E-3 UNIT A – LIGHTING PLAN (TYP.)
SCALE: 1/4"= 1'-0

LEGEND:

- SMOKE DETECTOR – SEE DRAWING
- 3/C — 3 WIRE PLUS GROUND WIRE
- 2 WIRE PLUS GROUND WIRE

1,414 SQUARE FOOT APARTMENT

Student Apartment - 2013

PANEL NO. NEW PANEL 'A1'

FED FROM ?

VOLTS 120/208 PH 1 W 3 G 1

MAIN CB MLO BUS 225A

SEPARATE NEUTRAL AND GROUND BUS
DO NOT BOND NEUTRAL TO GROUND

LOAD VA	LOAD DESCRIPTION	BREAKER DATA			CKT No.	PHASE	CKT No.	BREAKER DATA			LOAD DESCRIPTION	LOAD VA
		TRIP	POLES	TYPE				TYPE	POLES	TRIP		
900	BEDROOM #1 RECEPTS	20A	1	AFCI	1	A	2	AFCI	1	20A	BEDROOM #2 RECEPTS	900
1260	LIVING ROOM & HALLWAYS RECEPTS	20A	1	AFCI	3	B	4	AFCI	1	20A	BATHROOM RECEPT	720
360	KITCHEN RECEPTS – LEFT	20A	1	GFCI	5	A	6		1	20A	KITCHEN RECEPTS – RIGHT & ISLAND	720
4500	ELECTRIC WATER HEATER	20A	2		7	B	8		2	50A	ELECTRIC RANGE	8000
					9	A	10					
5000	ELECTRIC DRYER	20A	2		11	B	12		1	20A	MICROWAVE	1450
					13	A	14		1	20A	WASHING MACHINE	1500
690	AIR HANDLER & UTILITY RECEPT.	20A	2		15	B	16		1	20A	GARBAGE DISPOSAL	800
					17	A	18		1	20A	BEDROOM #2 & HALLWAY LGTS	500
200	LIVING ROOM & BALCONY LGTS	20A	1		19	B	20		1	20A	FRONT DOOR & UTILIY RM. LGTS	200
3500	HEAT PUMP	30A	2		21	A	22	GFCI	1	20A	OUTDOOR RECEPT.	250
					23	B	24		1	20A	DISHWASHER	
3000	BACK UP ELECTRIC COIL	20A	2		25	A	26				SPACE	
					27	B	28				SPACE	
600	BEDROOM #1 & HALLWAY LGTS	20A	1		29	A	30				SPACE	

NOTE:
SQUARE D TYPE NQ – 14" WIDE 240VAC, 3W, 1 POLE WITH 30 POLE LOCATIONS – MAIN LUG ONLY

3 / E–3 UNIT A – PANEL SCHEDULE (TYP.)
SCALE: N.T.S.

1,414 SQUARE FOOT APARTMENT

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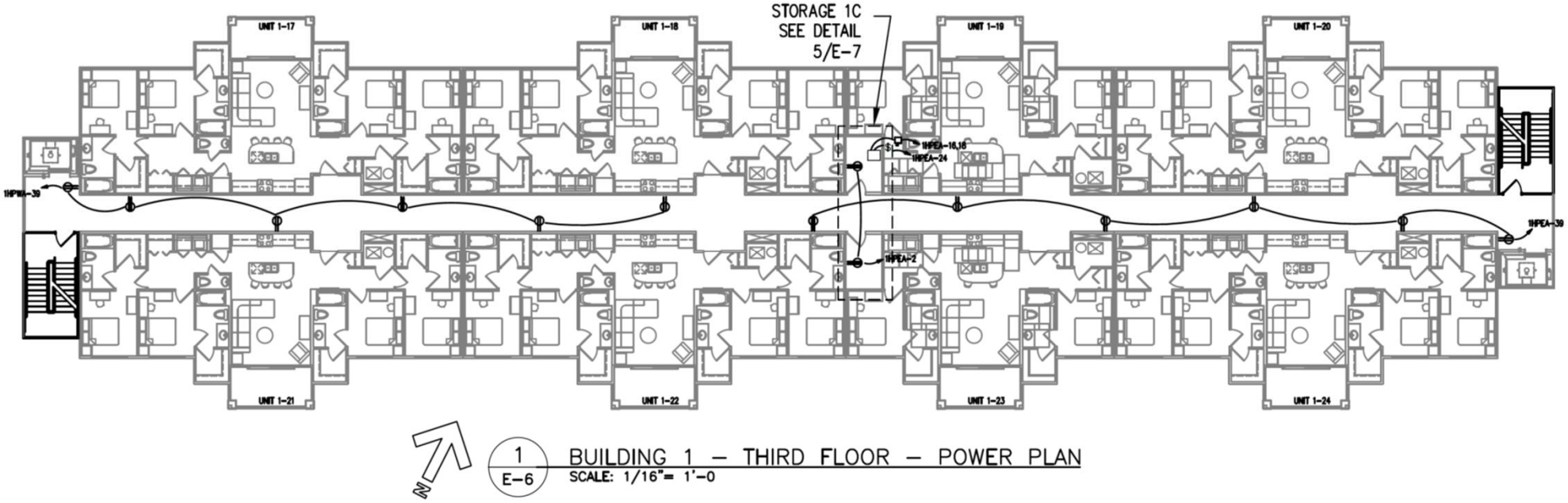

STUDENT APARTMENT BUILDING FLOOR PLAN WITH MULTIPLE UNITS

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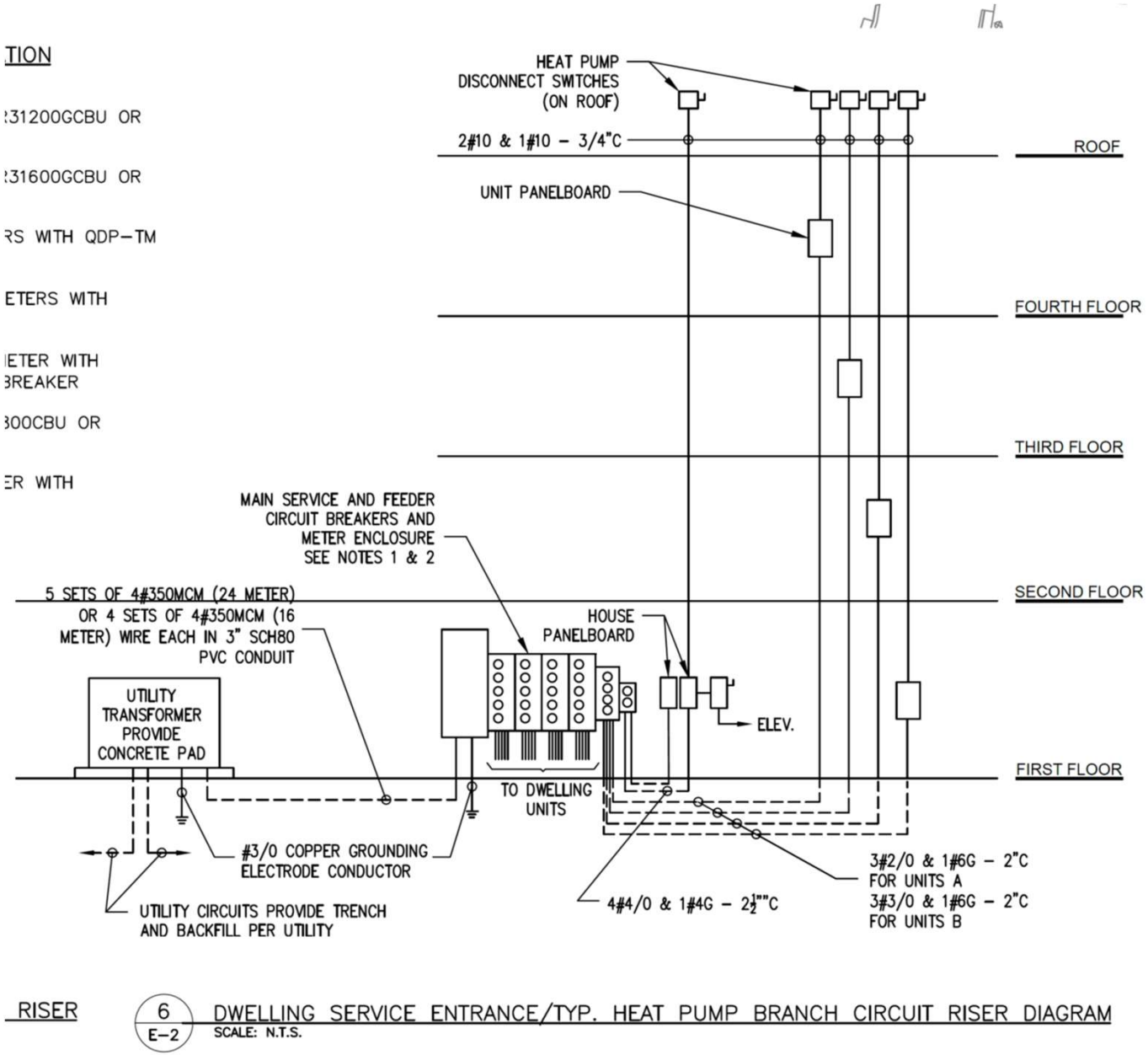
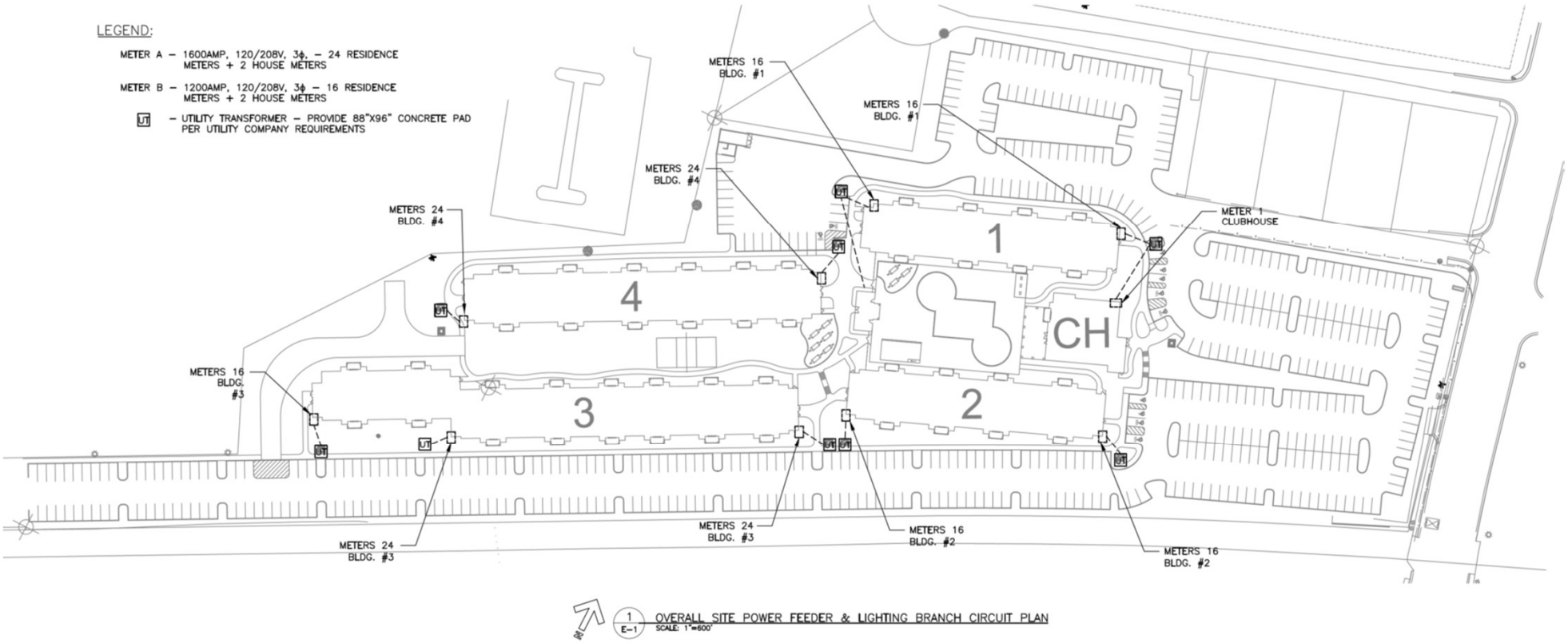


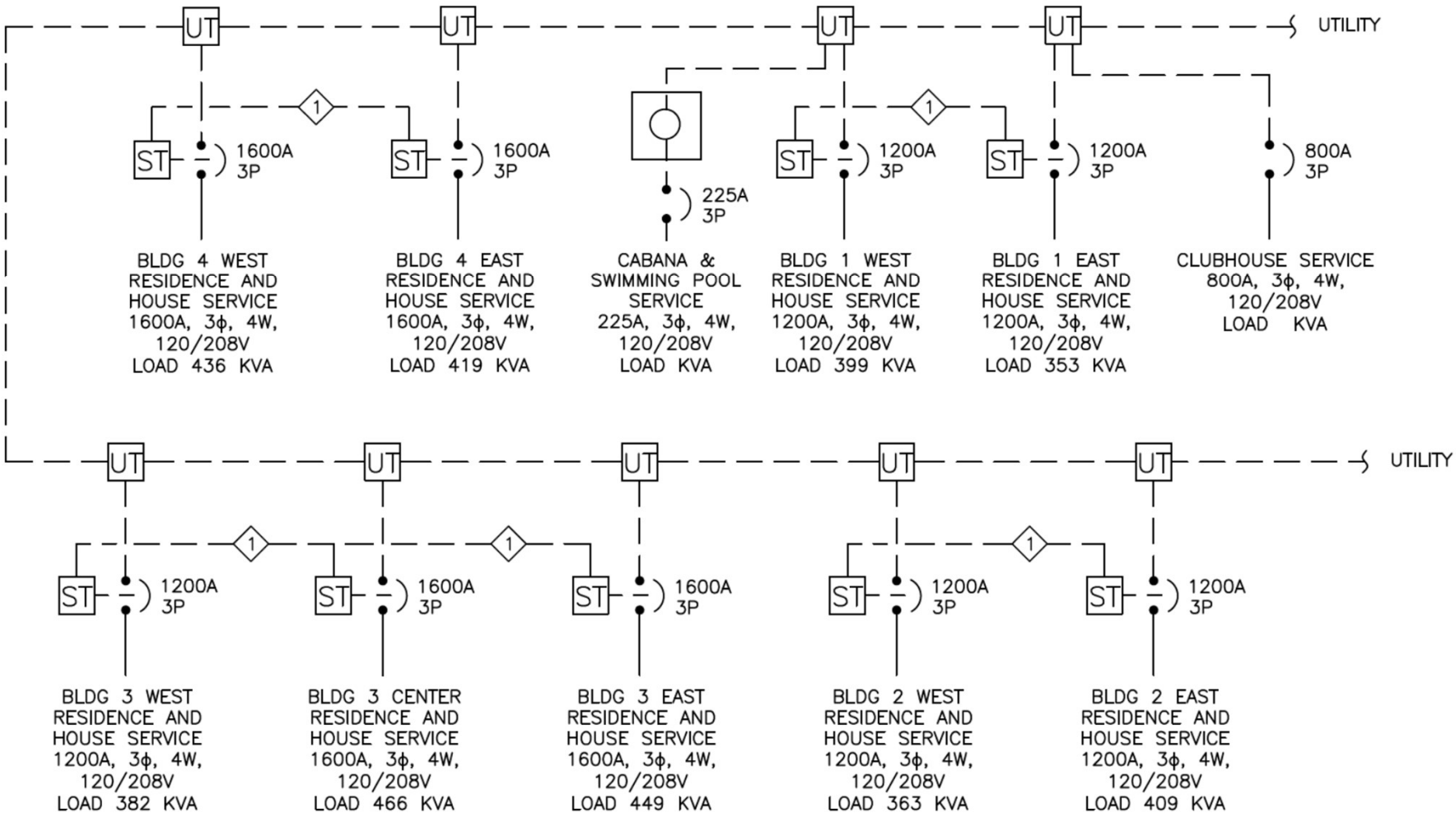
STUDENT APARTMENT BUILDING FLOOR PLAN WITH MULTIPLE UNITS FEEDER RISER DIAGRAM

Student Apartment Complex - 2013



STUDENT APARTMENT BUILDING OVERALL COMPLEX SITE PLAN

Student Apartment Complex - 2013



STUDENT APARTMENT BUILDING OVERALL COMPLEX SITE ONE LINE

Student Apartment Complex - 2013

Unit B Electrical Demand	VA		VA Total	VA Demand	CKT BREAKER
General Lighting & Required Circuits					
Square Feet	3	1414	4242		20/1
Kitchen Circuit	1500	2	3000		20/1
Laundry Circuit	1500	1	1500		20/1
Refrigerator	1440	1	1440		20/1
General Lighting & Required Circuits Total			10182	5513.7	
Electric Dryer	5000	1	5000	5000	30/2
Electric Range	8000	1	8000	8000	50/2
Air Handler	624	1	624	624	15/2
Heat Pump - 3 Ton	3744	1	3744	3744	40/2
Backup Electric Coil	3000	1	3000	3000	20/2
Other Appliances					
Microwave	1200	1	1200		20/1
Dishwasher	1200	1	1200		20/1
Garbage Disposal - 1/3 HP	864	1	864		20/1
Dryer Exhasut Booster Fan	87.6	1	87.6		15/1
Bathroom Exhaust Fans	108	4	432		20/1
Bedroom Fans	62.5	4	250		20/1
Living Room Fans	81.25	1	81.25		20/1
Electric Water Heater	5500	1	5500		35/2
Other Appliances Total			9614.85	7211.138	
Total VA			40164.85	33092.84	
	VA	AMPS		AMPACITY	VA
Amps at 208 Volt 1 Phase	33092.84	159.1		200	41600
	40164.85	193.1			

1,414 SQUARE FOOT APARTMENT

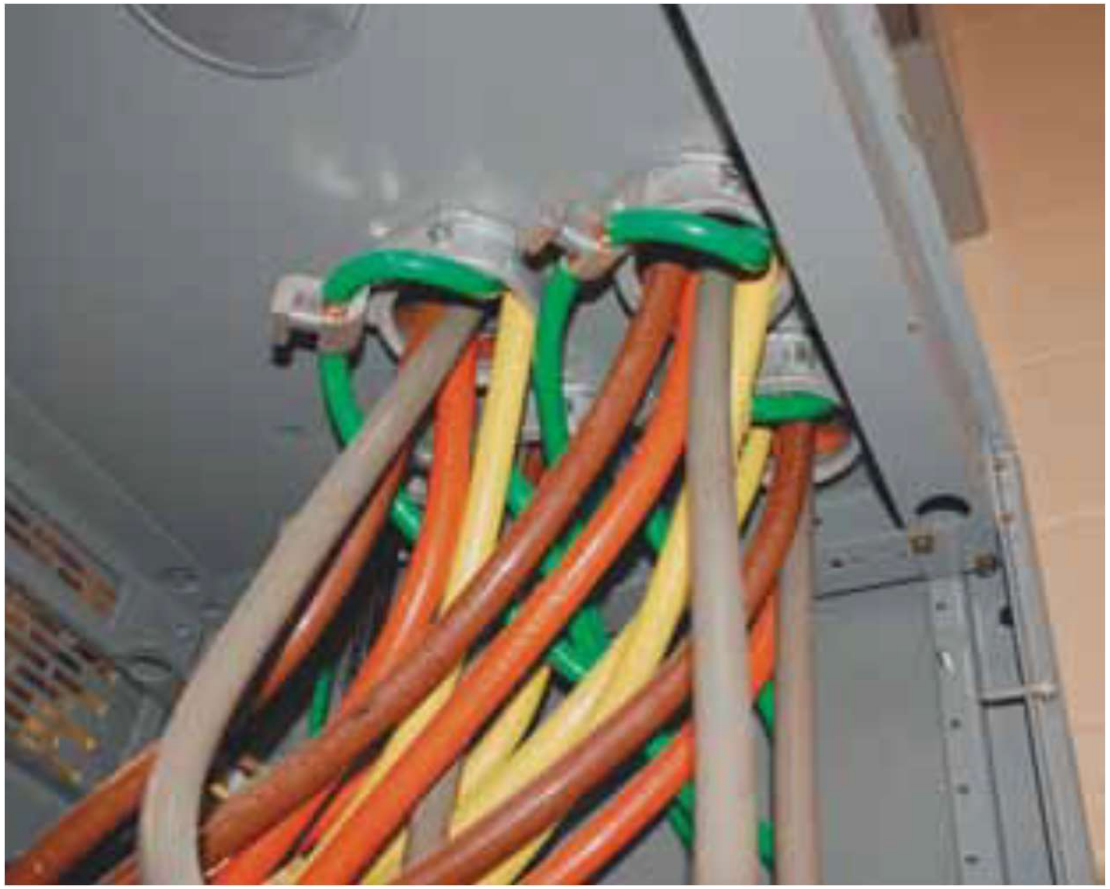
- 3 VA per square foot
- Kitchen – 3,000 VA
- Laundry – 1,500 VA
- Dryer – 5,000 VA
- Range – 8,000 VA
- HW Heater – 5,500 VA

TOTAL – 40,165 VA

DEMAND – 33,092 VA

REQUIRES A 151.9 AMPS 208 V, 1Ø FEEDER

Electrical Power Systems Basics



1Ø loads on 3Ø power systems must be accounted for by phase!

Coed wires are used to designate phase

At Home Vehicle Charging

ELECTRIC VEHICLE CHARGING

- CHARGING CABLE IS PROVIDED WITH CAR, SHOWN CONNECTED TO THE TESLA, CAN BE CONNECTED TO A PLUG ADAPTER WHICH IS PURCHASED SEPARATELY.

At Home Vehicle Charging

ELECTRIC VEHICLE CHARGING STATIONS

Supply Circuits – Single Phase, 120/240 Volt

- **20 amp, 120 volt circuit**
- **20 amp, 240 volt circuit**
- **30 amp, 240 volt circuit**
- **50 amp, 240 volt circuit**

Plug Adapter sets are available from Tesla

At Home Vehicle Charging

ELECTRIC VEHICLE CHARGING

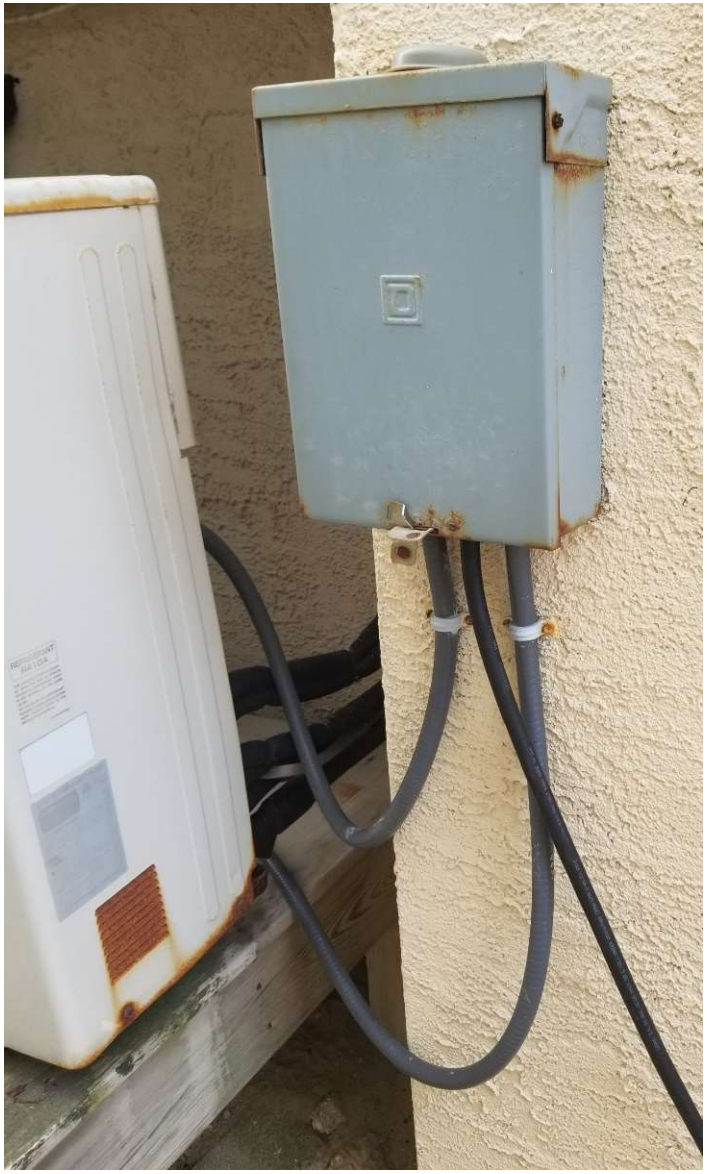
- 10-30 RECEPTACLE IS 240 VOLT WITH GROUND AND NO NEUTRAL
- ADAPTER PLUG CONNECTS TO TESLA CABLE
- HEAVY DUTY TYPE SJO, 3 CONDUCTOR #10 CABLE CONNECTS TO HOUSE POWER

At Home Vehicle Charging

ELECTRIC VEHICLE CHARGING

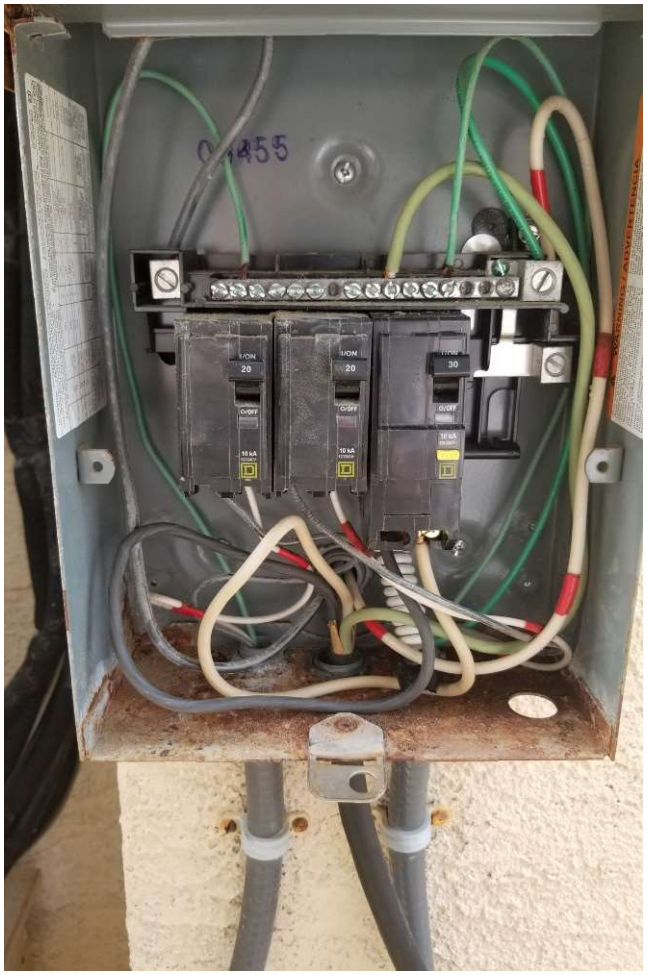
- OUTDOOR LOAD CENTER MADE THE "TEMPORARY" HOUSE CONNECTION EASY

- 30 AMP, 240 VOLT, GFCI CIRCUIT BREAKER REQUIRED BY THE NEC



At Home Vehicle Charging

ELECTRIC VEHICLE CHARGING



LOAD CENTER WITH THE
30 AMP GFCI CIRCUIT BREAKER INSTALLED

Electrical Power System NEC

ELECTRIC VEHICLE CHARGING STATIONS

Supply Circuits – Single Phase, 120/240 Volt

- **20 amp, 120 volt circuit – 2,400 VA – 16.6 hours to charge**
- **20 amp, 240 volt circuit – 4,800 VA**
- **30 amp, 240 volt circuit – 7,200 VA – 5.6 hours to charge**
- **50 amp, 240 volt circuit – 12,000 VA**
- **60 amp, 240 volt circuit – 14,400 VA**

Power Factor – 1 - Assumed

At $.15 per KWH – and 40,000 VAH for a full charge - $6.00

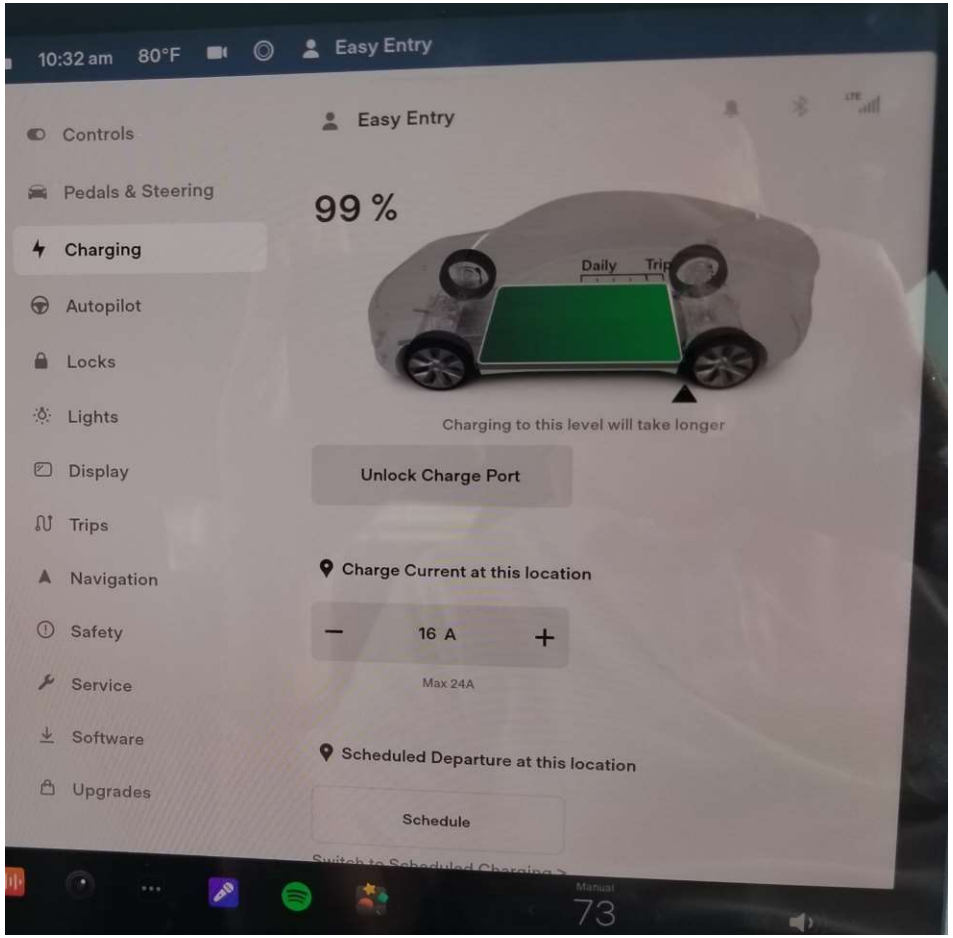
KWH = (VAH ÷ 1,000) X POWER FACTOR

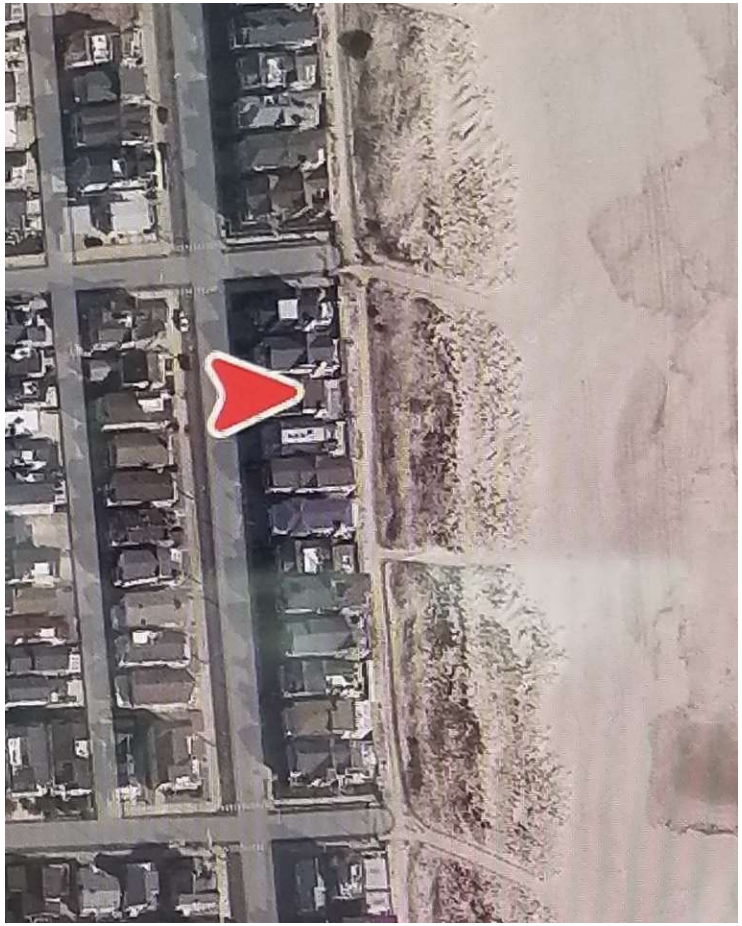
At Home Vehicle Charging

ELECTRIC VEHICLE CHARGING

Fully charged

What is Good for Car – May not be good for some houses





At Home Vehicle Charging

ELECTRIC VEHICLE CHARGING

May not be good for house

Why did the 30 Amp GFCI Circuit Breaker for the Tesla trip during the middle of the night?

Why do the Heat Pump Control Board fail?

What caused the resettable fault on the 240 volt Microwave?

Could it be 3rd Harmonics created by the Tesla?

Electrical Power Systems NEC

ARTICLE 110 Requirements for Electrical Installations

110.9 Interrupting Rating.

Equipment intended to interrupt current at fault levels shall have an interrupting rating at nominal circuit voltage at least equal to the current that is available at the line terminals of the equipment.

Equipment intended to interrupt current at other than fault levels shall have an interrupting rating at nominal circuit voltage at least equal to the current that must be interrupted.

Electrical Power Systems NEC

110.10 Circuit Impedance, Short-Circuit Current Ratings, and Other Characteristics.

The overcurrent protective devices, the total impedance, the equipment short-circuit current ratings, and other characteristics of the circuit to be protected shall be selected and coordinated to permit the circuit protective devices used to clear a fault to do so without extensive damage to the electrical equipment of the circuit.

This fault shall be assumed to be either between two or more of the circuit conductors or between any circuit conductor and the equipment grounding conductor(s).

Electrical Power System Basics

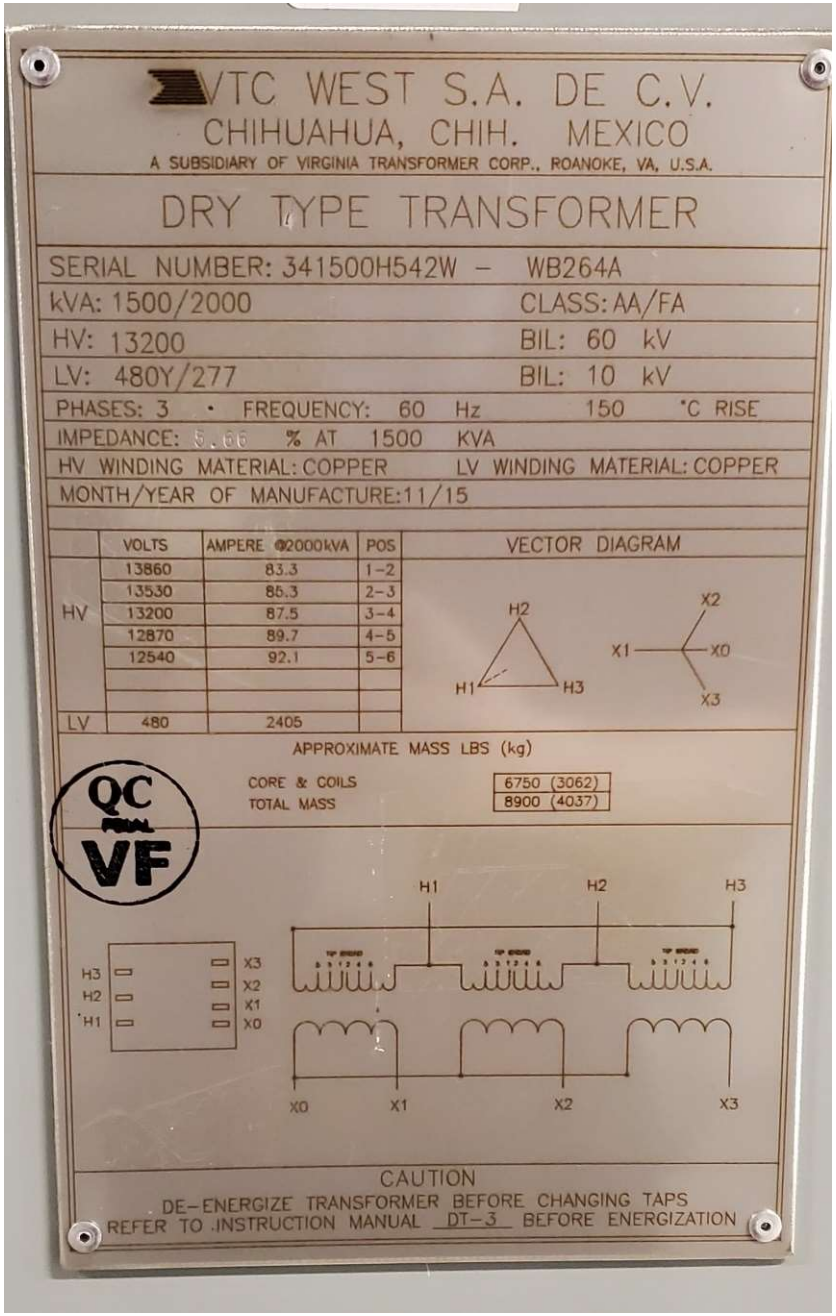
Transformers' nameplate impedances are "per unit" values based on transformers nameplate's Nominal KVA rating.

The following provide the worse case short circuit current for a 3Ø Transformer

$$KVA_{SC} = \frac{KVA_{nameplate}}{Z_{nameplate}}$$

$$I_{SC} = \frac{KVA_{SC} \times 100}{KV \times 1.732}$$

Electrical Power System Basics



Transformers nameplate:

KVA: 1500/2000

HV: 13200

LV: 480Y/277

IMPEDANCE: 5.66%

KVAsc =1500/.0566=26,503

Isc = 26,503/.48/1.732=

31,878 Amps

Short Circuit Calculations

When in doubt go to:

https://tools.se.app/faultcalc/FaultCalc.html

NEMA® defines Series Rating

A short-circuit interrupting rating assigned to a combination of two or more overcurrent protective devices which are connected in a series and in which the rating of the downstream device(s) in the combination is less than the series rating.

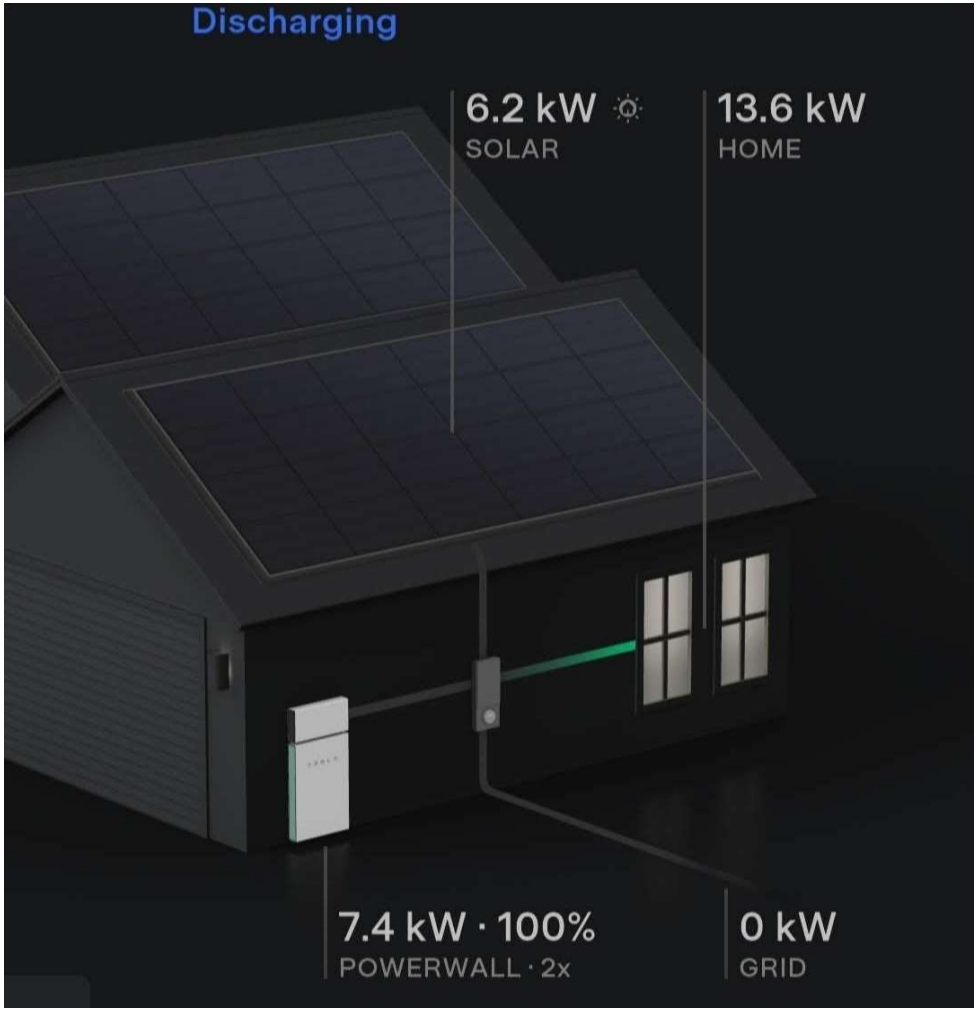
Electrical Power Systems NEC

Engineered Series Combination Systems.

Equipment enclosures for circuit breakers or fuses applied in compliance with series combination ratings selected under engineering supervision in accordance with 240.86(A) shall be legibly marked in the field as directed by the engineer to indicate the equipment has been applied with a series combination rating. The marking shall meet the requirements in 110.21(B) and shall be readily visible and state the following:

CAUTION — SERIES COMBINATION
SYSTEM RATED ____ AMPERES. IDENTIFIED
REPLACEMENT COMPONENTS REQUIRED.

At Home Power System



19.88 KVA At Home Power System with 13.6 KW Load

Photovoltaics – 6.2 KW

Tesla Power Wall 7.4 KW

At Home Power System

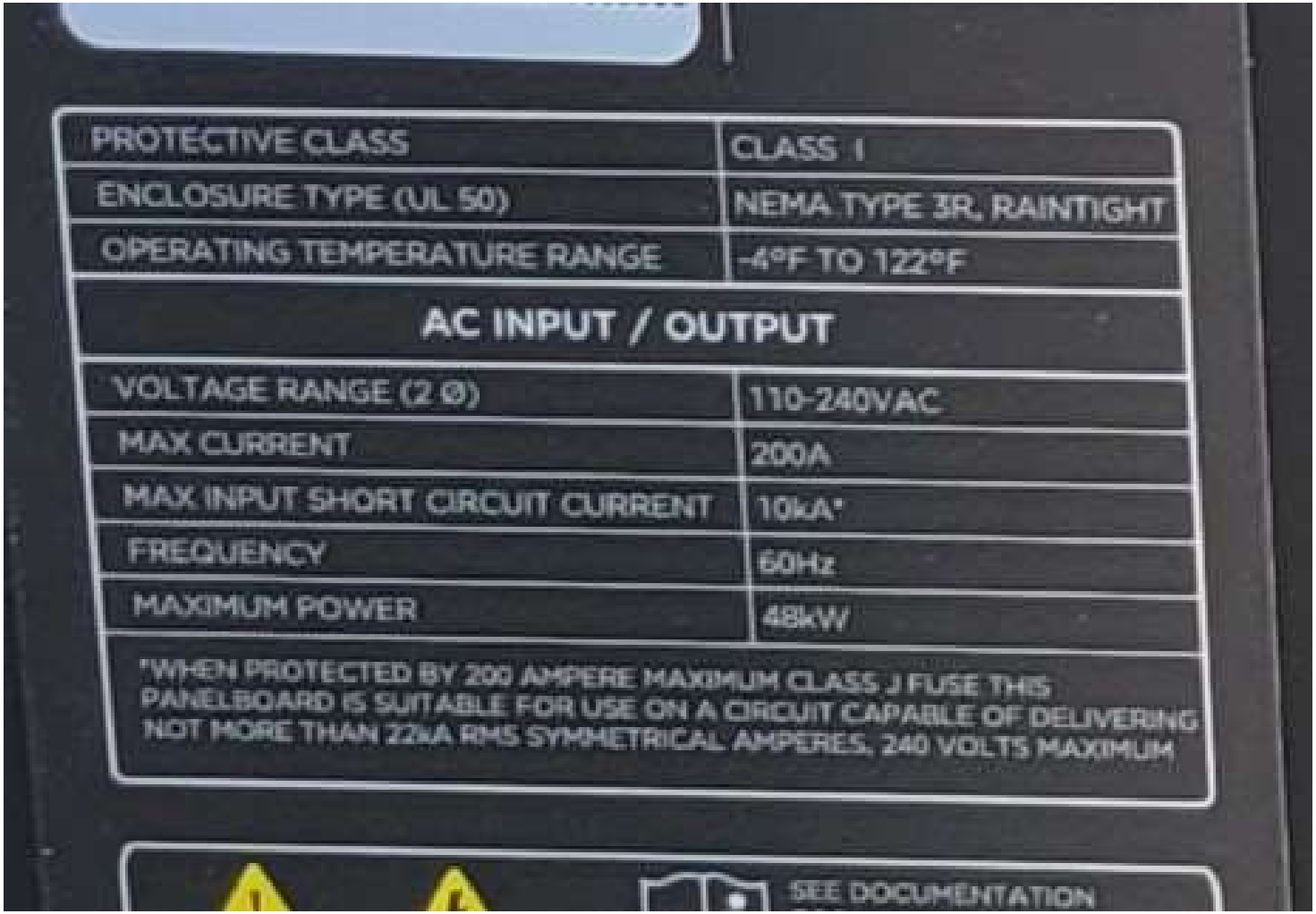
240 Volt - Circuit Breakers

50 Amp for Photovoltaics

30 Amp for Power Wall

200 Amp Main Circuit Breaker

At Home Power System



PROTECTIVE CLASS	CLASS I
ENCLOSURE TYPE (UL 50)	NEMA TYPE 3R, RAINTIGHT
OPERATING TEMPERATURE RANGE	-4°F TO 122°F
AC INPUT / OUTPUT	
VOLTAGE RANGE (2 Ø)	110-240VAC
MAX CURRENT	200A
MAX INPUT SHORT CIRCUIT CURRENT	10kA*
FREQUENCY	60Hz
MAXIMUM POWER	48kW

*WHEN PROTECTED BY 200 AMPERE MAXIMUM CLASS J FUSE THIS PANELBOARD IS SUITABLE FOR USE ON A CIRCUIT CAPABLE OF DELIVERING NOT MORE THAN 22kA RMS SYMMETRICAL AMPERES, 240 VOLTS MAXIMUM

SEE DOCUMENTATION

Short Circuit Current Rating

10,000 Amps – OK ???

At Home Power System

Typical 240/120 Volt Single-Phase Utility Transformers	
Rating	Available Short Circuit Current
1-10 kVA/1-ph	2778
1-25 kVA/1-ph	6944
1-50 kVA/1-ph	13889
1-75 kVA/1-ph	20833
1-100 kVA/1-ph	27778
1-167 kVA/1-ph	43490

Electric Vehicle NEC

Electric Vehicle - Definition

An automotive-type vehicle for on-road use, such as passenger automobiles, buses, trucks, vans, neighborhood electric vehicles, electric motorcycles, and the like, primarily powered by an electric motor that draws current from a rechargeable storage battery, fuel cell, photovoltaic array, or other source of electric current. Plug-in hybrid electric vehicles (PHEV) are considered electric vehicles.

For the purpose of this article, offroad, self propelled electric vehicles, such as industrial trucks, hoists, lifts, transports, golf carts, airline ground support equipment, tractors, boats, and the like, are not included.

Electric Vehicle Charging

2021 IECC - EV charging infrastructure requirements

R401.4 (IRC N1101.15) Plug-in electric vehicle charging.

Where parking is provided, new construction shall provide EVSE-installed spaces and facilitate future installation and use of EVSE through the provision of *EV-Ready Spaces* and *EV-Capable Spaces* provided in compliance with Sections R401.4.1 through R401.4.4 (IRC N1101.15.1 through IRC N1101.15.3).

Electric Vehicle Charging

2021 IECC - EV charging infrastructure requirements

R401.4 (IRC N1101.15) Plug-in electric vehicle charging.

Where more than one parking facility is provided on a site, electric vehicle ready parking spaces shall be calculated separately for each parking facility. The service panel or subpanel circuit directory shall identify the spaces reserved to support EV charging as "EV-Capable" or "EV-Ready".

The raceway location for *EV-Capable Spaces* shall be permanently and visibly marked as "EV-Capable".
PNNL-31576

Exception: This section does not apply to parking spaces used exclusively for trucks or delivery vehicles.

Electric Vehicle Charging

2021 IECC - EV charging infrastructure requirements

R401.4.1 (IRC N1101.15.1) Electric vehicle service equipment (EVSE) ready circuit.

Each *EV-Ready Space* shall be provided with a minimum 40-ampere branch circuit to accommodate a future dedicated Level-2 EVSE. The service panel shall provide sufficient capacity and space to accommodate the circuit and over-current protective device. A permanent and visible label stating "EV-READY" shall be posted in a conspicuous place at both the service panel and the circuit termination point.

Electric Vehicle Charging

2021 IECC - EV charging infrastructure requirements

R401.4.2 (IRC N1101.15.2) One- to two-family dwellings and townhouses. For each dwelling unit, provide at least one *EV-Ready Space*. The branch circuit shall be identified as "EV-Ready" in the service panel or subpanel directory, and the termination location shall be marked as "EV-Ready."

Exception: *EV-Ready Spaces* are not required where no parking spaces are provided

OTHER THAN DWELLINGS

220.87 Determining Existing Loads.

The calculation of a feeder or service load for existing installations shall be permitted to use actual maximum demand to determine the existing load under all of the following conditions:

(1) The maximum demand data is available for a 1-year period.

220.87 Determining Existing Loads - CONTINUED

(2) The maximum demand at 125 percent plus the new load does not exceed the ampacity of the feeder or rating of the service.

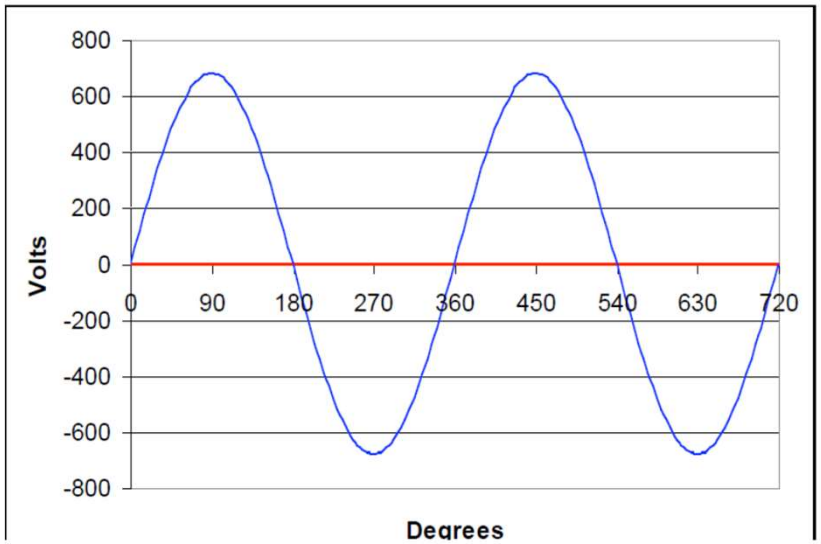
(3) The feeder has overcurrent protection in accordance with 240.4, and the service has overload protection in accordance with 230.90

Electrical Power System NEC

Exception: If the maximum demand data for a 1-year period is not available, the calculated load shall be permitted to be based on the maximum demand (the highest average kilowatts reached and maintained for a 15-minute interval) continuously recorded over a minimum 30-day period using a recording ammeter or power meter connected to the highest loaded phase of the feeder or service, based on the initial loading at the start of the recording. The recording shall reflect the maximum demand of the feeder or service by being taken when the building or space

Harmonics

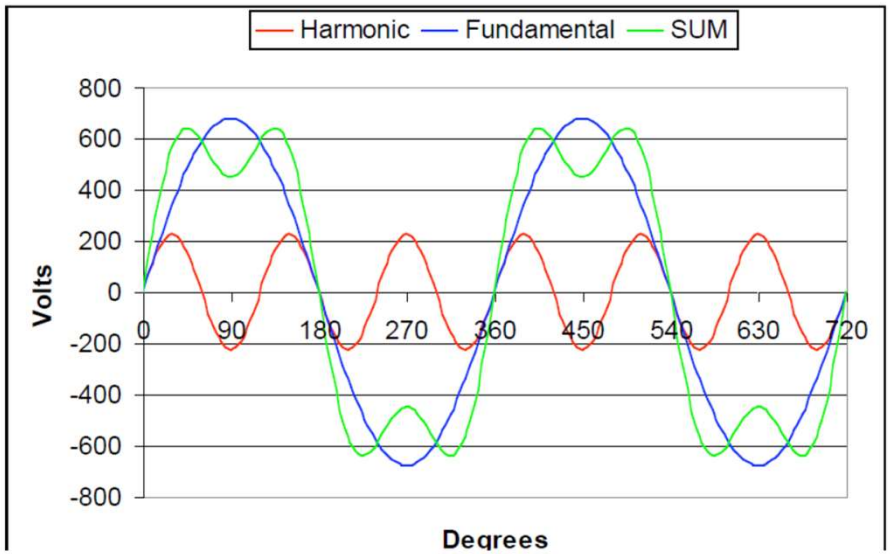
Any distortion of a sinusoidal waveform will result in a Fourier Series which is composed of a Fundamental Sine-Wave plus a series of harmonic components which are integer multiples of the fundamental



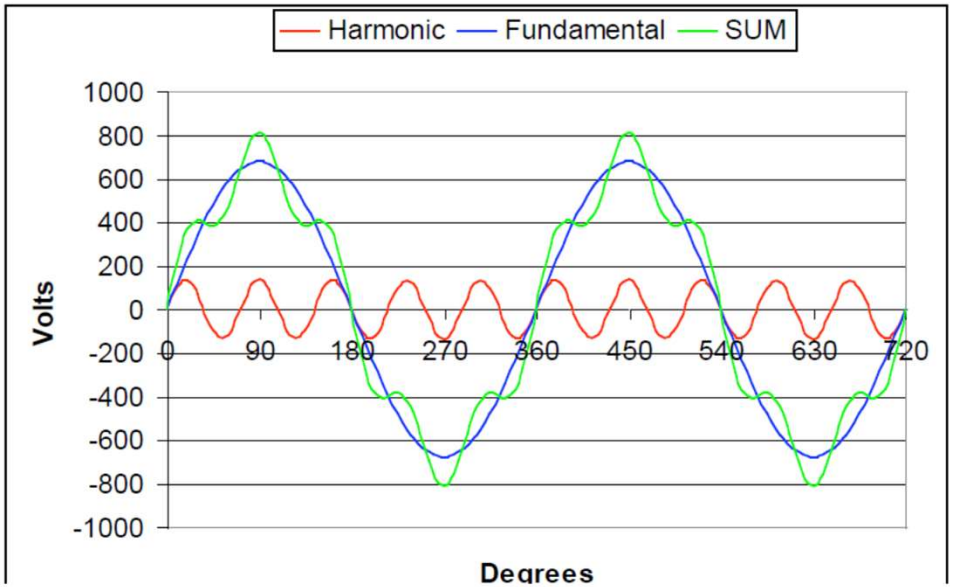
Fundamental Sine-Wave

Harmonic No.	Frequency
1	60 Hz
2	120 Hz
3	180 Hz
4	240 Hz
5	300 Hz
6	360 Hz
7	420 Hz
8	480 Hz
9	540 Hz

Harmonics



3rd Harmonic



5th Harmonic

Triplet Harmonic Adds up on Neutral

Harmonics

Load	1	3	5	7	9	11	13	15
6-Pulse Rectifier	100	-	17	11	-	5	3	-
12-Pulse Rectifier	100	-	3	2	-	5	3	-
18-Pulse Rectifier	100	-	3	2	-	1	0.5	-
24-Pulse Rectifier	100	-	3	2	-	1	0.5	
Electronic/Computer	100	56	33	11	5	4	2	1
Lighting/Electronic	100	18	15	8	3	2	1	0.5
Office with PC's	100	51	28	9	6	4	2	2
VFD's	100	-	65	41	-	8	8	-

- Harmonics in % of fundamental

Harmonics

- **Mis-operation of equipment with electronic circuits**
- **Nuisance tripping, blowing of fuses, OL trips**
- **High neutral-to-ground voltages (single-phase systems)**
- **Overheating & destruction of capacitor banks**
- **Equipment insulation failure due to high voltages**
- **Utility charges and fines; possible liability claims**

Harmonics

- Increased heating in conductors and other equipment
- Interference with communications, data processing, plant control systems
- De-rating of power supplies & transformers; ties up system capacity
- Premature aging of electrical insulation
- Increased heating and reduced torque in motors

Harmonics

ELECTRIC VEHICLE CHARGING

May not be good for house

Why did the 30 Amp GFCI Circuit Breaker for the Tesla trip during the middle of the night?

Why do the Heat Pump Control Board fail?

What caused the resettable fault on the 240 volt Microwave?

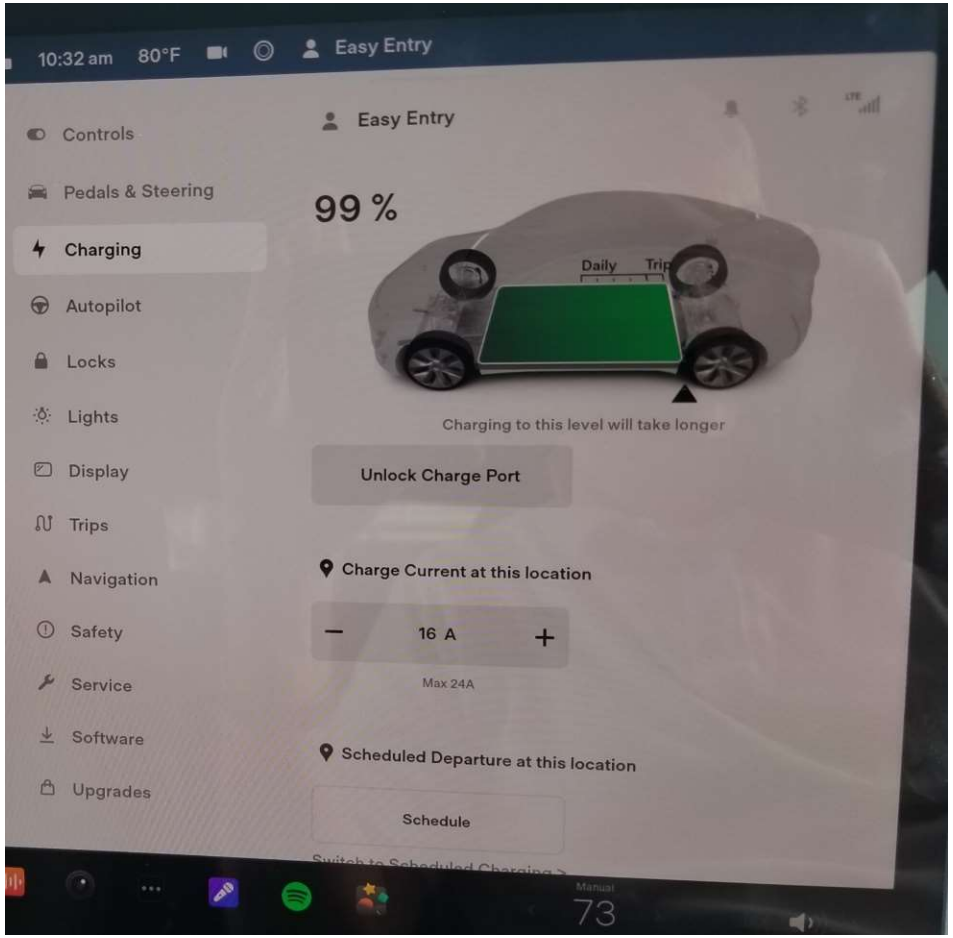
Could it be 3rd Harmonics created by the Tesla?

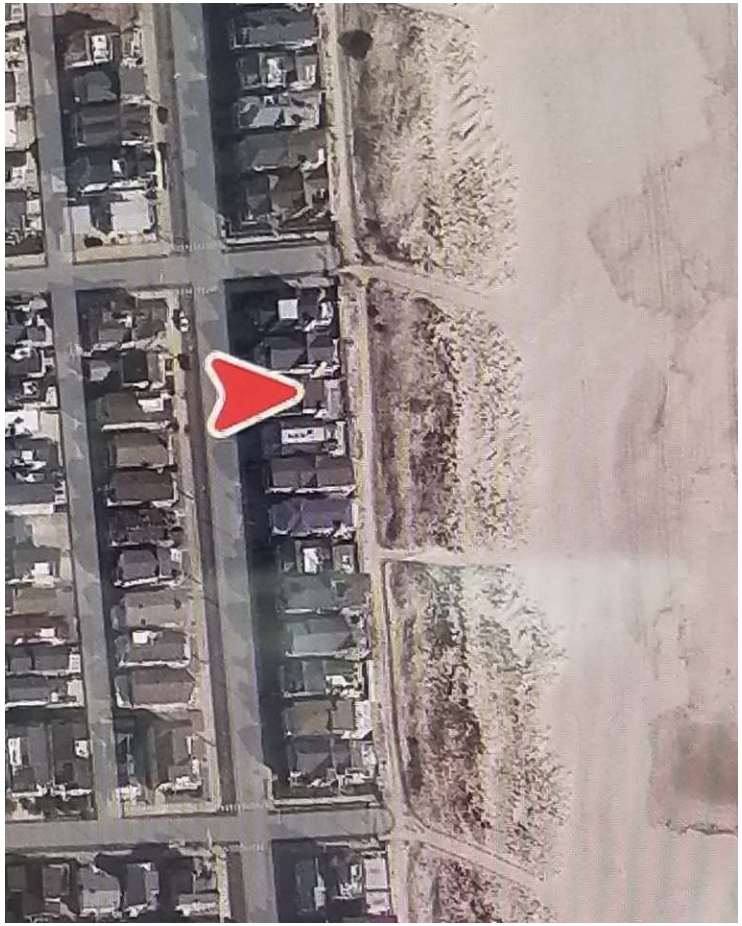
At Home Vehicle Charging

ELECTRIC VEHICLE CHARGING

Fully charged

What is Good for Car – May not be good for some houses





Harmonics

K-Rated Transformers

- Designed for nonlinear or harmonic generating loads that a standard transformer could not adequately handle due to overheating.
- Assembled with a double sized neutral conductor, heavier gauge copper and either change the geometry of their conductors or use multiple conductors for the coils.
- Designed to endure the additional heat caused by harmonic currents.

Harmonics

For any given nonlinear load, if the harmonic current components are known, the K-factor can be calculated and compared to the transformer's nameplate K-factor.

The higher the K-factor, the more non-linear loads the transformer can handle.

Standard K-factors are 4, 9, 13, 20, 30, 40, and 50.

Harmonics

Rule of thumb

- **0% electronic, 100% electrical – standard (K-1 rated) transformer**
- **25% electronic, 75% electrical – K-4 rated transformer**
- **50% electronic, 50% electrical – K-9 rated transformer**
- **75% electronic, 25% electrical – K-13 rated transformer**
- **100% electronic, 0% electrical – K-20 rated transformer***

"electronic" = Nonlinear Loads
"electrical" = Inductive and Resistive Loads

*** - Use Phase Shifting Transformers where applicable.***

PHASE SHIFT

The currents and voltage on a delta–wye or wye–delta transformer have a 30° phase difference between the primary and the secondary. Wye–wye and delta-delta transformer have no phase shift between the primary and secondary.

Delta-wye transformers act as an open circuit and prevent the triplet harmonics (3rd, etc.) from passing through the transformer. Thus, the transformer acts as a natural harmonics filter, the distortion spectrum and distortion waveform for buses downstream of delta-wye transformers will be smoother. The transformers will need to be K rated.

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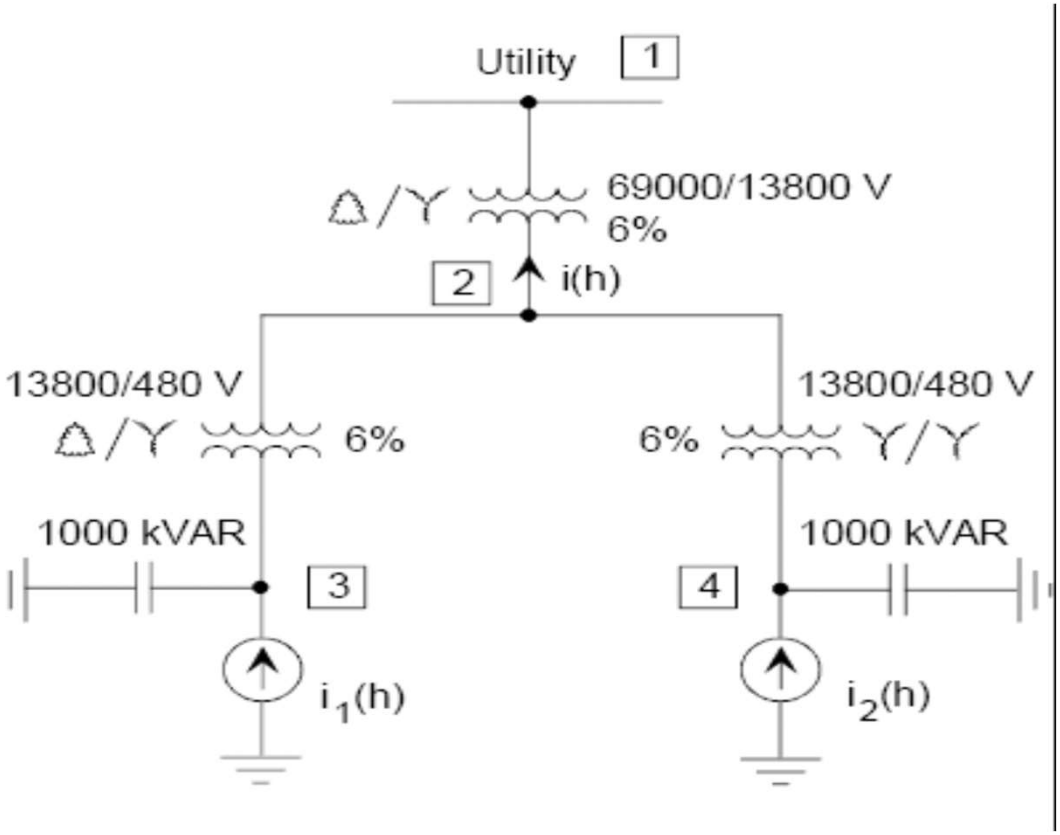
PHASE SHIFT



12 Pulse Application

PHASE SHIFT

In a 12 Pulse Application

- **The 5th harmonic current from the source on the secondary side of the Δ/Y transformer is shifted by 30° on the primary side of the transformer.**
- **The Y/Y connected transformer has 0° phase shift,**
- **Therefore, the sum of the 5th and 7th order of harmonic currents flowing from the transformers into the utility is zero.**

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PHASE SHIFT

Building a VFD with multiple 6 pulse converters and phase shifting transformers makes it is possible to reduce the harmonics that will be fed back to the power system dramatically. The following is a diagram for a twelve pulse VFD.

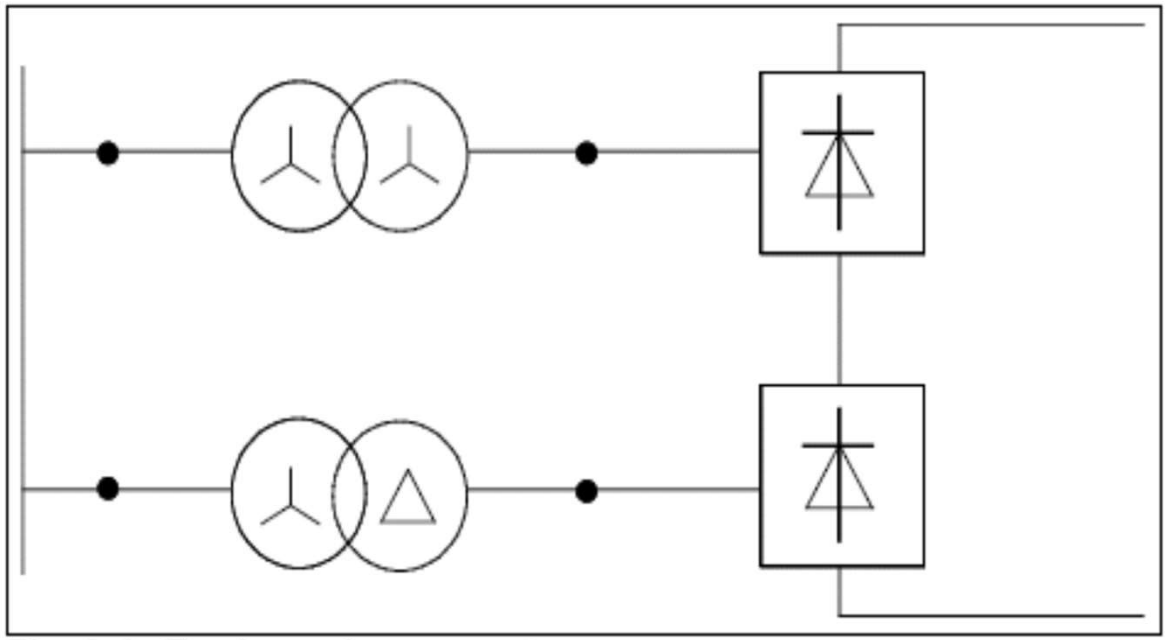

Fig. 2-4. Twelve pulse converter.

Harmonics

IEEE STD 519-2014 - IEEE Recommended Practice and Requirements for Harmonic Control in Electrical Power Systems

- Establishes goals for the design of electrical systems that include both linear and nonlinear loads.
- Describes the voltage and current waveforms that may exist throughout the system and establishes the waveform distortion goals for the system designer.

Test Questions

1. **What version of the Standard for Electrical Safety in the Workplace® is the latest version?**

2. **Does a 120/240 V, single phase panelboard in single family home requires an arc flash marking?**

3. **Can electrical vehicle charging stations be connected to any residential dwelling?**

MAIDA ENGINEERING INC

Test Questions

4. **Must series rated be identified when used with fully rated circuit breakers?**

5. **What likely caused the 30 Amp GFCI circuit breaker to trip when charging the Tesla?**

6. **When a circuit breaker trips, what should you do first?**

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Questions?

THANK YOU!

www.MaidaEngineering.com

Joseph F. Maida, PE
215 353 6110
215.542.8700
jmaida@maidaeng.com