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APPLYING DEMAND FACTOR AND DIVERSITY FACTOR PER THE *NEC*

Don't be confused by these terms!

There are two terms used in calculating loads in electrical systems that cause designers to get confused. These terms are "demand factor" and "diversity factor." To better understand how these terms are applied when calculating loads, you must understand their meaning.

Demand factor is the ratio of the maximum demand of a system, or part of a system, to the total connected load on the system, or part of the system under consideration. Demand factor is always less than one.

Diversity factor is the ratio of the sum of the individual maximum demands of the various subdivisions of a system, or part of a system, to the maximum demand of the whole system, or part of the system, under consideration. Diversity factor is usually more than one.

For example, these terms, when used in an electrical design, should be applied as follows:

The sum of the connected loads supplied by a feeder-circuit can be multiplied by the demand factor to determine the load used to size the components of the system. The sum of the maximum demand loads for two or more feeders is divided by the diversity factor for the feeders to derive the maximum demand load.

Given:
Consider four individual feeder-circuits with connected loads of 250 kVA, 200 kVA, 150 kVA and 400 kVA and demand factors of 90%, 80%, 75% and 85% respectively. Use a diversity factor of 1.5.

Solution:
Calculating demand for feeder-circuits

- 250 kVA x 90% = 225 kVA
- 200 kVA x 80% = 160 kVA
- 150 kVA x 75% = 112.5 kVA
- 400 kVA x 85% = 340 kVA

837.5 kVA

The sum of the individual demands is equal to 837.5 kVA

If the main feeder-circuit were sized at unity diversity:

kVA = 837.5 kVA ÷ 1.00 = 837.5 kVA

The main feeder-circuit would have to be supplied by an 850 kVA transformer.

However, using the diversity factor of 1.5, the kVA = 837.5 kVA ÷ 1.5 = 558 kVA for the main feeder.

For diversity factor of 1.5, a 600 kVA transformer could be used.

Note that a 600 kVA transformer can be used instead of an 850 kVA when applying the 1.5 diversity factor.

DEMAND FACTOR

Although feeder-circuit conductors should have an ampacity sufficient to carry the load, the ampacity of the feeder-circuit need not always be equal to the total of all loads on all branch-circuits connected to it. A study of the following sections will show that, in some cases, a "demand factor" may be applied to the total load. Remember, the demand factor permits a feeder-circuit ampacity to be less than 100% of the sum of all branch-circuit loads connected to the feeder.

APPLYING DEMAND FACTOR FOR GENERAL LIGHTING 220.3(A); TABLE 220.3(A)

Section 220.3(A) of the *NEC*® governs the rules for calculating the lighting load on services and feeder-circuits. The difference between calculating branch-circuit loads and feeder-circuit loads is that a demand factor is not usually applied for a branch-circuit, but may be applied in the case of a feeder-circuit. **The load on a service or feeder is the sum of all of the branch loads subject to their demand factors as permitted by the rules of this Section.**

"Demand factor" is a percentage by which the total connected load on a service or feeder is multiplied to determine the greatest probable load that the feeder will be called upon to carry. In hospitals, hotels, apartment complexes, and dwelling units, it is not likely that all of the lights and receptacles connected to every branch-circuit served by a service or feeder would be "on" at the same time. Therefore, instead of sizing the feeder to carry all of the load on all of the branches, a percentage can be

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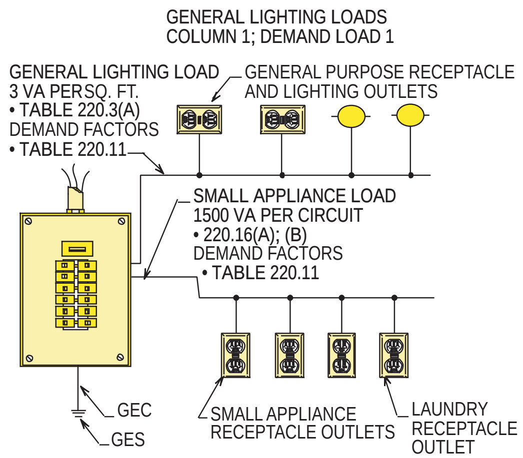
applied to this total load, and the components sized accordingly.

Referring to Table 220.11 of the *NEC*, it can be seen that a demand factor for lighting may be applied only for dwelling units, hospitals, hotels, motels, and warehouses. All other occupancies are calculated on a basis of total computed lighting wattage, and no demand factor is permitted. **(See Figure 1)**



What is the demand load for the general lighting load of a 3500 sq. ft. dwelling unit?

Step 1:	Calculating the VA Table 220.3(A) 3500 sq. ft. x 3 VA	= 10,500 VA
Step 2:	220.16(A);(B) 1500 VA x 3	= 4,500 VA
Step 3:	Total loads General lighting load Small appliance load Total	= 10,500 VA = 4,500 VA = 15,000 VA
Step 4:	Applying demand factors Table 220.11 First 3000 VA x 100% Next 12,000 VA x 35% Total	= 3,000 VA = 4,200 VA = 7,200 VA
Solution:	Demand load 1 is 7200 volt amps.	

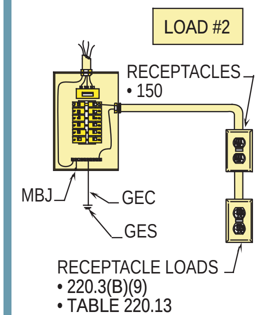
Figure 1. The above illustration shows the calculation of a demand factor load for a dwelling unit using Table 220.11

Figure 1

APPLYING DEMAND FACTOR FOR RECEPTACLES 220.13; TABLE 220.13

Section 220.13 of the *NEC* makes it clear that in dwelling units, general-purpose receptacles are not counted as a load. In other than dwelling units, a minimum of 180 VA is computed for each general-purpose receptacle. For hospitals, hotels, motels, and warehouses, this receptacle load can be lumped with the lighting load, and the demand factors of Table 220.11 may be applied to the total.

General-purpose receptacle outlets used to cord-and-plug connect loads are considered to have noncontinuous operation and are calculated per **220.3(B)(9)** and **Table 220.13**. Noncontinuously operated receptacles with a VA rating of 10,000 VA or less shall be computed at 100 percent. If the VA rating of the receptacle load exceeds 10,000 VA, a demand factor of 50 percent should be applied to all VA exceeding 10,000 VA per **Table 220.13**. **(See Figure 2)**



CALCULATING RECEPTACLE LOAD AND APPLYING DEMAND FACTORS

Step 1:	Calculating VA 220.3(B)(9); 230.42(A)(1) 150 x 180 VA = 27,000 VA	
Step 2:	Applying demand factors Table 220.13 First 10,000 VA x 100% = 10,000 VA Next 17,000 VA x 50% = 8,500 VA 18,500 VA	
Solution:	The demand load for the receptacles is 18,500 VA.	

Figure 2. The demand load for general-purpose receptacles for other than dwelling units is computed by using Table 220.13.

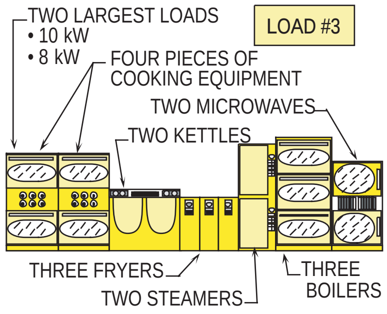
Figure 2

APPLYING DEMAND FACTOR FOR COMMERCIAL COOKING EQUIPMENT 220.20; TABLE 220.20

Section 220.20 in the *NEC* permits Table 220.20 to be used for load computation for commercial electrical cooking equipment, such as dishwashers, booster heaters, water heaters and other kitchen equipment. The demand factors shown in Table 220.20 are applicable to all equipment that is thermostatically controlled or is only intermittently used as part of the kitchen equipment. In no way do the demand factors apply to the electric heating, ventilating or air-conditioning equipment. In computing the demand, the demand load should not be less than the sum of the two largest kitchen equipment loads. **(See Figure 3)**

APPLYING DEMAND FACTOR FOR THE NEUTRAL 220.22

Section 220.22 of the *NEC* states that for a service or feeder, the maximum unbalanced load controls the ampacity selected for the grounded (neutral) conductor. The grounded (neutral) conductor service or feeder load should be considered wherever a grounded (neutral) conductor is used in conjunction with one or more ungrounded (phase) conductors. On a single-phase feeder



CALCULATING LOAD FOR COOKING EQUIPMENT

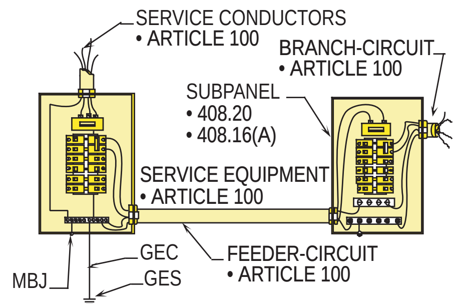
Step 1: Calculating percentage
Table 220.20
16 pieces allowed 65%

Step 2: Applying demand factors
Table 220.20; 220.20
82 kW x 65% = 53.3 kVA

Solution: The demand load of 53.3 kVA is greater than the sum of the two largest loads of 18 kVA.

Figure 3. The demand load for commercial cooking equipment is computed based upon the number and the percentage per Table 220.20

Figure 3



ASSUME THE FOLLOWING LOADS AND COMPUTE THE NEUTRAL LOAD

Step 1: Calculating total neutral load
220.22

Discharge lighting loads	= 300 amp per phase
Incandescent lighting loads	= 50 amp per phase
Other resistive loads	= 295 amp per phase
Total neutral loads	= 645 amp per phase

Step 2: Applying demand factors for inductive and resistive loads
220.22

First 200 amp x 100%	= 200 amps
Next 145 amps x 70%	= 101.5 amps
Resistive loads	= 301.5 amps
Discharge lighting at 100%	= 300 amps
Total neutral load	= 601.5 amps

Solution: The neutral load after demand factors that have been applied is 601.5 amps.

Figure 4. The above calculation shows the procedure for computing the neutral for a service or feeder and applying demand factors per 220.22.

Figure 4

using one ungrounded (phase) conductor and a grounded (neutral) conductor, the grounded (neutral) conductor will carry the same amount of current as the ungrounded (phase) conductor. A two-wire feeder is seldom used, so in considering the grounded (neutral) feeder current, always assume that there is a grounded (neutral) conductor and two or more ungrounded (phase) conductors. If there are two ungrounded (phase) conductors that are connected to the same phase, and a grounded (neutral) conductor, the grounded (neutral) conductor would be required to carry the total current from both ungrounded (phase) conductors, which would not be an accepted practice.

For three-wire DC or single-phase AC, four-wire three-phase, three-wire two-phase, and five-wire two-phase systems, a further demand factor of 70 percent should be applied to that portion of the unbalanced load in excess of 200 amperes. There should be no reduction of the grounded (neutral) conductor ampacity for that portion of the load that consists of electric-discharge lighting, electronic computer/data processing or similar equipment, when supplied by four-wire, wye-connected, three-phase systems.

(See Figure 4)

APPLYING DEMAND FACTOR FOR CONNECTING ADDITIONAL LOADS TO EXISTING INSTALLATIONS 220.35

When additional loads are connected to existing facilities having feeders and service as originally computed, the maximum kVA computations in determining the load on the existing feeders and service should be used if the following conditions are met:

- If the maximum data for the demand in kVA, such as demand meter ratings, is available for a minimum of one year.
- If 125 percent of the demand ratings for the period of one year added to the new load does not exceed the rating of the service. Where demand meters are used, in most cases the load as computed will probably be less than the demand meter indications.

(See Figure 5)

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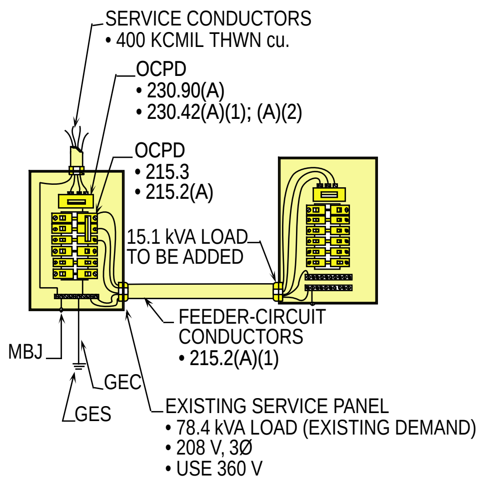


CALCULATING LOAD IN AMPS

Step 1: Finding demand
220.35
Maximum demand = 78.4 kVA

Step 2: Calculating existing demand
78.4 kVA x 125% = 98 kVA

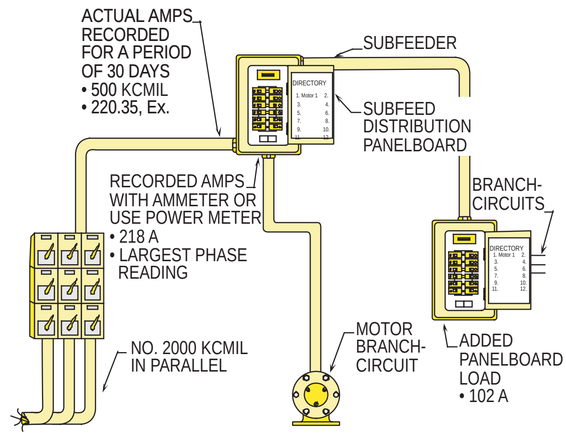
Step 3: Calculating total kVA
230.42(A)(1)
98 kVA + 15.1 kVA = 113.1 kVA

Step 4: Calculating amperage
Table 310.16
No. 400 KCMIL THWN copper = 335 A
113.1 kVA x 1000 = 113,100 VA
113,100 VA ÷ (208 x 1.732) = 314 A
314 A is less than 335 A

Solution: The 15.1 kVA demand load can be applied to the existing service without upgrading the elements.

Figure 5. The above illustration is the calculation for adding a load to an existing service or feeder-circuit using 220.35.

Figure 5



NOTE: ADDED LOAD FOR A SERVICE CAN BE COMPUTED, USING THE SAME PROCEDURE PER 220.35, Ex.

CALCULATING LOAD IN AMPS

Step 1: Finding recorded demand
220.35
Maximum demand = 218 A

Step 2: Calculating existing demand
218 A x 125% = 273 A

Step 3: Calculating existing and added load
273 A + 102 A = 375 A

Step 4: Finding amperage for feeder conductors
Table 310.16
500 KCMIL THWN copper = 380 A

Step 5: Determining if load can be added
375 A is less than 380 A

Solution: The 375 amp load can be applied to the existing feeder-circuit conductors.

Figure 6. The above illustration shows the optional calculation being applied for adding a load to an existing feeder-circuit using 220.35.

Figure 6

APPLYING DEMAND FACTOR TO THE EXCEPTION TO 220.35

220.35, Ex.

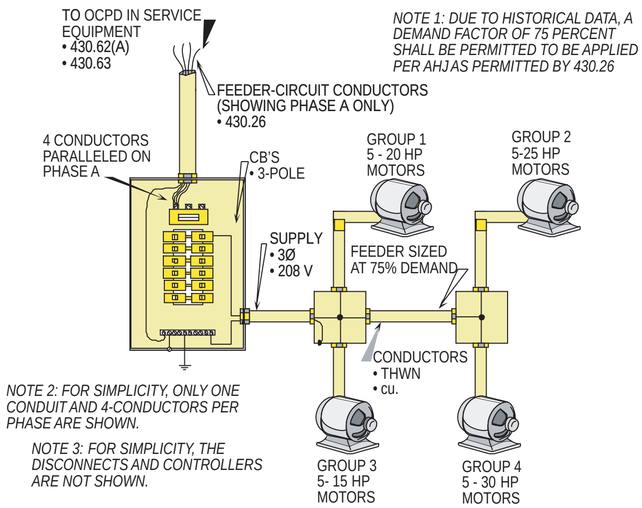
If the maximum demand data for a one year period is not available, the calculated load is permitted to be based on the maximum demand (measure of average power demand over a 15-minute period) continuously recorded over a minimum 30 day period using a recording ammeter or power meter connected to the highest loaded ungrounded (phase) of the feeder or service, based on the initial loading at the start of the recording.

(See Figure 6)

APPLYING DEMAND FACTOR FOR MOTORS 430.26

There are, in some cases, motor installations where there may be a special situation in which a number of motors are connected to a feeder-circuit. Because of the particular application, certain motors do not operate together and the feeder-circuit conductors are permitted to be sized based on a historical demand factor.

For example, the authority having jurisdiction may grant permission to allow a demand factor of less than 100 percent if operation procedures, production demands, or the nature of the work is such that not all the motors are running at one time. An engineering study or evaluation of motor operation may provide information that will allow a demand factor of less than 100 percent. **(See Figure 7)**



Sizing Largest Motor Load

Step 1: Calculating amps of motors
Table 430.150
15 HP = 46.2 A x 5 = 231 A
20 HP = 59.5 A x 5 = 297 A
25 HP = 75.8 A x 5 = 374 A
30 HP = 88 A x 5 = 440 A
Total Load = 1342 A

Step 2: Applying demand factors
430.26
1342 A x 75% = 1007 A

Solution: The demand load is 1007 amps.

Sizing Conductors

Step 1: Paralleling 4 lines per phase
310.4
Amps per conductor = 1007 A ÷ 4
Amps per conductor = 252 A

Step 2: Sizing conductor for feeder
Table 310.16
252 A requires 250 KCMIL THWN cu. conductors
250 KCMIL THWN cu. = 255 A
255 A x 4 = 1020 A
1020 A supplies 1007 A

Solution: The size THWN copper conductors are 4 - 250 KCMIL per phase.

Figure 7. The above illustration shows the sizing of a feeder-circuit using 430.26

Figure 7

CONCLUSION

For engineers and contractors, the above demand factors are the most widely used on a regular basis because of their uniqueness to electrical design. With the application of demand factors, smaller components can be utilized in the electrical system and greater savings can be passed on to the consumer. Due to the high cost of wiring, look for designers to utilize these techniques more than ever before.

Additional information on this topic may be found in chapters 22 and 23 of the book 'Stallcup's Electrical Design Book, 2002 Edition,' available from the NFPA.