

Pumping Up Power to Oil-Well Units

Designing an electrical system to supply a group of oil-well pumping units is a project that calls for some slick calculations.

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It's not everyday you have to design an electrical distribution system to serve a number of oil-well pumping units. When faced with this task, make sure you design the system so your transformer banks and secondary line conductors can start and run the motors that will power the pumping units connected to the lines. What's the best way to complete this task? Let's run through the steps required to knock out a great design in little time.

Designing the system. First, determine the amount of power necessary to serve the system. Base the amount on the number of pumping units you plan to install. Then, develop the layout of the site based on the size and location of each pumping unit and

establish the point at which the utility company will deliver the power. Next, select the secondary voltage to match the voltages listed on the nameplates of the motors and other associated equipment. Finally, select the transformer bank required to supply the total kVA necessary for the electrical loads. A general rule of thumb is to provide at least 1kVA of transformer capacity for each horsepower of

each load (number of pumping units). The **Figure**, on page 56, depicts a typical supply system serving an oil-field pumping unit.

Sizing conductors. The conductors you select for this type of distribution system should be the smallest conductors necessary to allow the largest pump motor to start, run, and operate satisfactorily. You



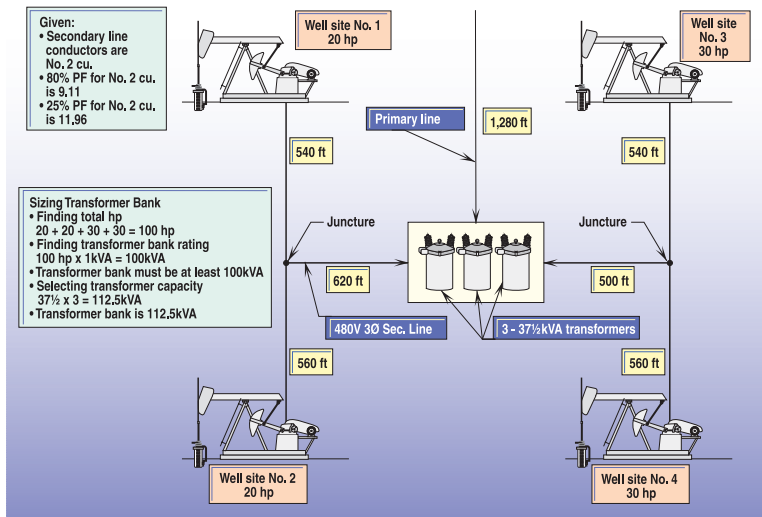
Size your conductors correctly, or the sun may set on the life of your oil pumps.

must also take into account voltage drop (VD) in the load and in the line during your calculations. The maximum permissible voltage drop is typically between 5% and 10% with all motors running and between 15% and 25% with any one motor starting.

You'll find conductor size makes all the difference in these calculations. This is because the resistance of a conductor is proportional to its length and inversely proportional to its diameter.

Size conductors using the kVA/ft procedure, which is based on the fact that 1 hp equals 1kVA. To calculate voltage drop during motor starting, assume the starting kVA to be 6 × the running kVA because of the high starting current of the motor. Whether you base this on the conductors supplying power to the farthest motor or on the conductors

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A typical supply system serving an oil-field pumping unit.

supplying power to the largest motor depends on which gives the greater kVA/ft measurement. Let's go through an example to see how this works.

Consider the well site depicted in the figure, which is supplied by a 3-phase line of four pumping units with 460V motors. Determine the primary and secondary conductors capable of supplying the required power for all four sites. Assume the power factor (PF) of a running motor is 80%, the starting power factor of a motor is 25%, and the voltage drop is 10% for running and 20% for starting. For the motor kVA, use 6× the running kVA of the motor.

To perform the calculation, select the most critical load first. This is the motor that gives the greatest kVA/ft. Well sites No. 2 and No. 4 will be used for this computation due to their horsepower ratings of 20 hp and 30 hp, respectively. Note that the figure shows well sites No. 2 and No. 4 to be furthest from the transformer bank.

Using a formula that's been used in the oil field for years (we'll refer to it as the *Rule of Thumb Method*), calculate the kVA/ft as follows:

$$\text{Well site No. 2 (20 hp} \times 560 \text{ ft)} + (40 \text{ hp} \times 620 \text{ ft)} = 36 \text{ kVA/ft}$$

$$\text{Well site No. 4 (30 hp} \times 560 \text{ ft)} + (60 \text{ hp} \times 500 \text{ ft)} = 46.8 \text{ kVA/ft.}$$

Note that well site No. 4 has a greater kVA/ft measurement than well site No. 2.

Using the higher kVA/ft value from above (46.8kVA) and assuming the use of No. 2 copper conductors, calculate the voltage drop for well site No. 4 as follows:

$$\text{Voltage drop (VD)} = 46.8 \text{ kVA} \div 9.11$$

(See Table, below, for origin of this number.)

$$\text{VD} = 5.14\%$$

Note that the 5% voltage drop calculated is well within the 10% required for the calculation.

To calculate the voltage drop with one motor running at well site No. 3 and one motor starting at well site No. 4, use a 25% power factor for the starting motor and 6× the running kVA. Compute the kVA/ft for well site No. 3 and well

site No. 4. The sum of the voltage drops for the two sites will derive the total voltage drop for one pump motor running and one pump motor starting.

Apply the Rule of Thumb Method again to calculate the voltage drop for well site No. 3 with motor running. Use the distance from juncture noted in the figure.

$$30 \text{ hp} \times 540 \text{ ft} = 16.2 \text{ kVA/ft at 80\% PF}$$

$$\text{VD} = 16.2 \text{ kVA} \div 9.11$$

$$\text{VD} = 1.78\%$$

Calculate the voltage drop for well site No. 4 with motor starting. Use distance from juncture noted in the figure.

$$30 \text{ hp} \times (560 \text{ ft} + 560 \text{ ft}) \times 6 = 201.6 \text{ kVA/ft at 30\% PF}$$

$$\text{VD} = 201.6 \text{ kVA} \div 11.96 \text{ (see the table for origin of this number)}$$

$$\text{VD} = 16.86\%$$

Therefore, the total voltage drop is 1.78% + 16.86%, or 18.64%. This is less than the 20% allowable voltage drop for starting conditions. Therefore, the No. 2 copper conductors are adequate to start and run the four motors operating the four oil-field pumping units. You can also use No. 4 copper conductors if capacitors are designed and sized properly and installed on the line. Note that 1 hp equals 0.75kVA when capacitors are used to improve power factor on the secondary line.

This discussion of sizing the secondary conductors required to supply motors powering a number of oil-field pumping units has been simplified in an effort to explain an otherwise complex calculation procedure. Today, many oil-field companies rely on computer programs to perform these computations and select the most economical size conductors for the job.

Voltage Drop for Secondary Line kVA-ft (provides 1% VD)		
Conductor	Percent power factor	kVA-ft (thousands)
No. 2 cu.	80% (motor running)	9.11
No. 2 cu.	30% (motor running)	11.96

Use this table to determine voltage drop values.

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