Distribution and Use of Electric Power

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INTRODUCTION

In our daily contact with oil company personnel, the most frequently asked questions are about the design of the electric distribution systems, operating voltage levels, rules and regulations pertaining to pole heights and wire clearances, and protective equipment for electric motors. We will try to answer these questions. Let's begin with voltages.

22 KV PRIMARY

In the lease distribution system we are concerned with 2 voltages. The high or primary voltage, and the low or secondary voltage.

The primary voltage is usually that voltage which the electric company delivers to your lease. This service voltage will vary from one company to another within a limited range. The commonly used service voltages are 12,470, 13,200, 13,800, and 14,400. As new oil fields have been added to the electric company's lines, the added load and added length of lines have caused voltage regulation problems. To solve this problem, many companies are going to service voltages of 22,000 and 24,000. This higher voltage requires some changes in the construction of your primary line. These changes involve number of wires, insulation, grounding and transformer connections.

A common neutral conductor should be installed on all primary poles and connected to the electric company's neutral. Pole grounds should be installed on transformer bank poles and on a minimum of 5 poles per mile in the primary line. There should be an interconnection between system neutral, transformer tank, lightning arresters, and pole grounds. Fig. 1 shows the location of the pole ground and the system neutral. It is good practice, but not required, to have pole grounds on your 12,470 to 14,400 volt primary lines also.

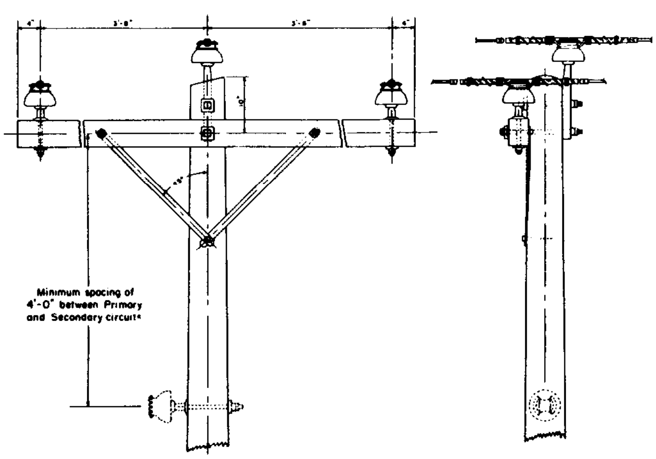

Fig. 1 Primary Line Pole

Normally you use Class 55-3 (13.5 KV) pintype insulators and Class 52-1 suspension insulators. On the 22 or 24 KV primary line you should use Class 55-4 (17.5 KV) pintype insulators and add 1 additional suspension insulator where you deadend the center phase. Fig. 2 is an illustration of a primary deadend structure with 2 suspension insulators per phase for 14,400 volt construction. In this illustration we are using steel crossarm braces. For 22 KV construction, you should use wooden braces.

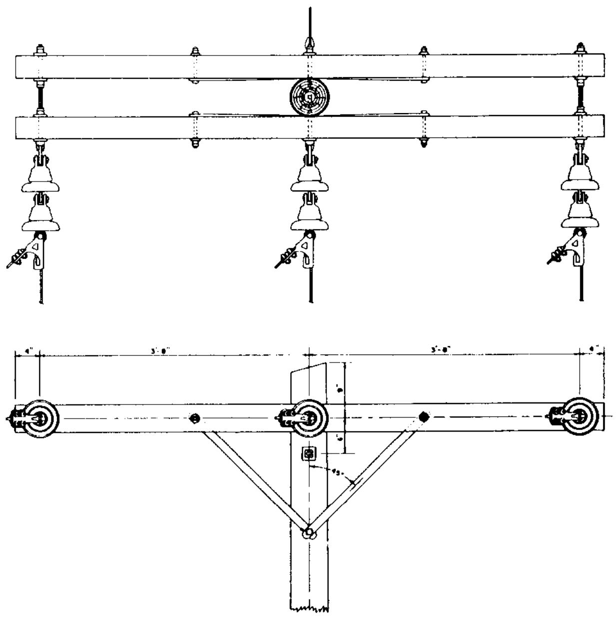

Fig. 2 Primary Deadend Pole

On the 22 KV or 24 KV transformer bank it is recommended that you use 15 KV fuse cutouts and 15 KV expulsion type lightning arresters. See Fig. 3. Nominally rated 12 KV or 14.4 KV transformers may be used; however, they must be connected wye instead of delta.

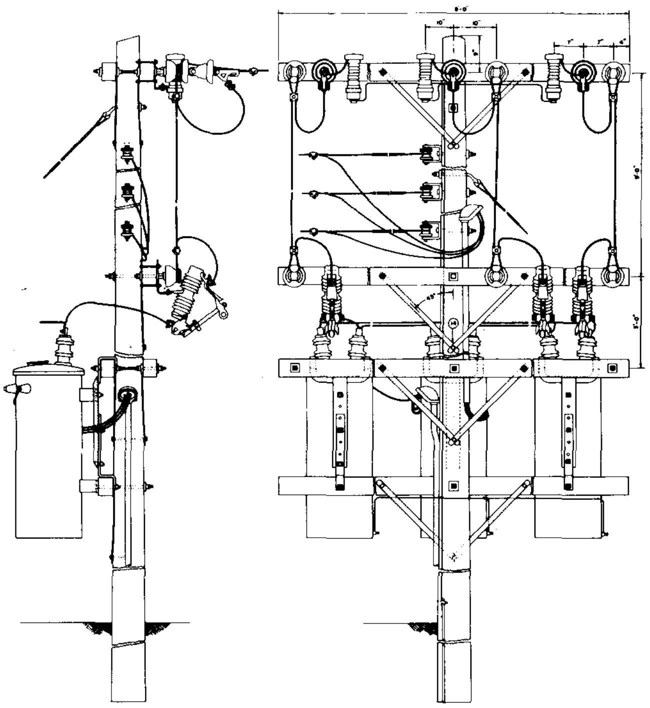

Fig. 3 Single Pole Substation

If you have a large system and want to install sectionalizing fuse cutouts, use those rated at 27 KV. To prevent accidents and equipment damage, it is a good idea to put a sign on each pole denoting that it is a "22 KV" or "24 KV" electric line.

762 VOLT SECONDARY

For the same reasons that the electric company has felt the need for a higher service voltage, the lease operator may occasionally want a higher secondary, or operating voltage. When this need arises, several companies are now putting in a 762 Volt system. The 762 Volt system is a variation of the 440 Volt system.

The most widely used secondary system in the oil field is 440 Volt, 3 phase. This voltage is usually obtained by using delta - connected single phase transformers. These same transformers may be reconnected and used for the 762 Volt Wye - solidly - grounded system. The neutral must be solidly grounded to minimize overvoltages on the phase conductors under fault conditions. The 440/762 Volt Wye - solidly - grounded system gives 762 Volt phase-to-phase. You will also see this system referred to as 480/831. In either case, you multiply your standard voltage of 440 or 480 by 1.73 to obtain the higher voltage of 762 or 831.

With the higher operating voltage, your motor amperage is decreased by a proportionate amount. Therefore, you can serve three times the load of a 440 Volt system using the same size conductor. Or, you can serve the same load over a distance three times that of the 440 Volt system. This fact enables you to use smaller conductor and still maintain the same voltage regulation when you are designing a new system. As a "Rule of Thumb", you can estimate the 762 Volt distribution system as 8% lower in cost than the 440 Volt system serving the same load over the same distance. However, in comparing the two systems, you must take into account the cost of 440/762 volt motor controls and capacitors and the added cost of grounding the 762 Volt system. One disadvantage of using longer secondary lines is the increased exposure to lightning.

At this time, there are 3 lease distribution systems in general use. They are 440 Volt secondary distribution, 762 Volt secondary distribution, and primary distribution wherein you locate a transformer station at each well. There is a place for each system. The most economical system for you to use will be determined by motor size, number of motors, and distances involved. Consideration might also be given to standardization of voltage within a given area or company.

For designing and estimating the cost of a lease distribution system, the unit prices shown on Tables 1 through 4 will be helpful. These prices include the cost of materials, labor, transportation, tools, and insurance.

TABLE 1 -- Cost of Primary Line Structures

Code No.	Description		Price
P-1	Tangent Primary Structure on 35' Pole		
		12.5 KV	$47.00
		22 KV	50.00
P-2	Primary Deadend Structure on 35' Pole		
		12.5 KV	79.00
		22 KV	85.00
P-3	Primary Deadend on Existing Pole		
		12.5 KV	52.00
		22 KV	58.00
P-4	Tangent Primary Structure with Double Pins and Crossarms on 35' Pole		
		12.5 KV	62.00
		22 KV	68.00
P-5	Primary 10 to 60 Degree Angle Structure on 35' Pole		
		12.5 KV	112.00
		22 KV	122.00
P-6	Primary 90 Degree Turn Structure on 35' Pole		
		12.5 KV	130.00
		22 KV	143.50

TABLE 2 -- Cost of Secondary Line Structures

Code No.	Description	Price
S-1	Tangent Secondary Structure on 30' Pole	31.50
S-2	Secondary Deadend on 30' Pole	37.50
S-3	Secondary Deadend on Existing Pole	10.50
S-4	Tangent Secondary Structure on Existing Pole.	6.00
S-5	Secondary 90 Degree Turn Structure on 30' Pole	48.50

TABLE 3 -- Cost of Transformer Substation

Code No.	Description		Price
T-1	Single Pole with 3-10 KVA, Single Phase Transformers	12.5 KV	$830.00
		22.0 KV	895.00
T-2	Single Pole with 3 - 15 KVA, Single Phase Transformers	12.5 KV	990.00
		22.0 KV	1,055.00
T-3	Single Pole with 3 - 25 KVA, Single Phase Transformers	12.5 KV	1,145.00
		22.0 KV	1,210.00
T-4	Single Pole with 1 - 15 KVA, 3 Phase Transformer	12.5 KV	625.00
T-5	Single Pole with 1 - 30 KVA, 3 Phase Transformer	12.5 KV	775.00
T-6	Single Pole with 1 - 45 KV, 3 Phase Transformer	12.5 KV	950.00
T-7	Three Pole with 3 - 37-1/2 KVA Single Phase Transformers	12.5 KV	1,650.00
		22.0 KV	1,730.00
T-8	Three Pole with 3 - 50 KVA Single Phase Transformers	12.5 KV	1,790.00
		22.0 KV	1,870.00

TABLE 4 -- Cost of Conductor, Guys and Anchors

Code No.	Description	Price
C-1	No. 4 ACSR Conductor	$46.50/M'
C-2	No. 2 ACSR Conductor	61.50/M'
C-3	No. 1/0 ACSR Conductor	86.50/M'
C-4	No. 2/0 ACSR Conductor	99.00/M'
C-5	No. 4/0 ACSR Conductor	140.00/M'
G-1	Secondary Line Guy and Anchor	25.00
G-2	Primary Line Guy and Anchor	27.50

NATIONAL ELECTRICAL SAFETY CODE

The National Electrical Safety Code is written by the Commerce Department of the United States. It is often referred to in specifications, but is not enforced directly by the government. It is offered as a guide and should be followed by prudent companies. It will help you avoid trouble with your electrical system and with the public. The Code should be regarded as minimum specifications since accepted practice oftentimes exceed code requirements. Table 5 summarizes our recommendations for minimum pole heights, clearances, and maximum span lengths.

TABLE 5 -- Pole Height and Span Length

Pole Length Voltage of Line's (1)	30' Secondary only	35' Secondary only	35' Primary only	35' Primary & Secondary	40' Primary & Secondary
Maximum Span Length over Rural and Lease Roads (2)					
No. 4 ACSR	320'	435'	460'	385'	435'
No. 2 ACSR	305'	420'	420'	370'	420'
No. 1/0 ACSR	300'	420'	420'	370'	420'
Maximum Span Length over Open Country (3)					
No. 4 ACSR	425'	435'	460'	435'	435'
No. 2 ACSR	415'	420'	420'	420'	420'
No. 1/0 ACSR	415'	420'	420'	420'	420'

Notes:
(1) 750 Volt Secondary and 12 KV Primary
(2) Minimum Clearance to Ground of 18 Ft.
(3) Minimum Clearance to Ground of 15 Ft.

MOTOR PROTECTIVE DEVICES

The subject of motor protection has taken on increased significance in recent years as motor buyers attempt to use motors to their maximum rated capacity and minimize motor failures at the same time.

Excessive heating of motor windings which may cause burnouts can be caused in several ways. Some conditions, such as locked rotor, stalling, single phase, and extreme overload, cause a rapid rise in temperature. Other conditions, such as running overloads, plugging, increased ambient temperatures, voltage fluctuations, and blocked ventilation may cause a gradual temperature rise. The best motor protector is the one whose operating characteristics parallel the condition in the motor. The trick is to develop a device which will parallel all conditions.

Protective devices can be divided into two basic categories, remote and internal. Remote devices are overload relays, fuses, and circuit breakers. These devices are designed to measure or sense the current in a line and react when the current exceeds a predetermined amount. The overload relay is the standard protective device used throughout the country, and is, generally, very satisfactory. There are conditions, such as overheating due to blocked ventilation and unbalanced voltage, when the overload relay will not provide complete protection.

The second type of protective device is internal. It is either embedded in or adjacent to the motor windings and senses the actual heating inside the motor. In some instances, the word "inherent" is applied to these protectors, although as defined by Underwriters Laboratories, to be "inherent" a protector must sense both current and temperature. To avoid confusion, we will use the term "internal motor protector".

The oldest form of "internal motor protection" is the thermostat. This device is mounted on the stator coil head and utilizes a bimetallic snap-acting switch to sense temperature changes. Since heat from the motor winding must pass through the winding insulation and then through the case of the thermostat, there is a thermal lag. The thermostat does a good job of protecting where the temperature rise is gradual. It is not satisfactory for rapid temperature increases such as occur during a locked rotor condition or single phasing.

A later form of "internal motor protector" is the "Klixon" over-heat protector, built by Spenser Division of Texas Instruments. See Fig. 4. It combines the best features of the current responsive external overload relay and the temperature responsive thermostat. Being mounted in the motor, it carries motor current through a heater coil and bimetallic disc. This allows the protector to anticipate high motor temperature by sensing the excessive currents caused by locked rotor and heavy overloads. The "Klixon" protector thus furnishes complete protection against burnouts. However, since the device carries motor current and is mounted internally, its use is limited to smaller, low current motors. It is presently available through 7-1/2 H.P.

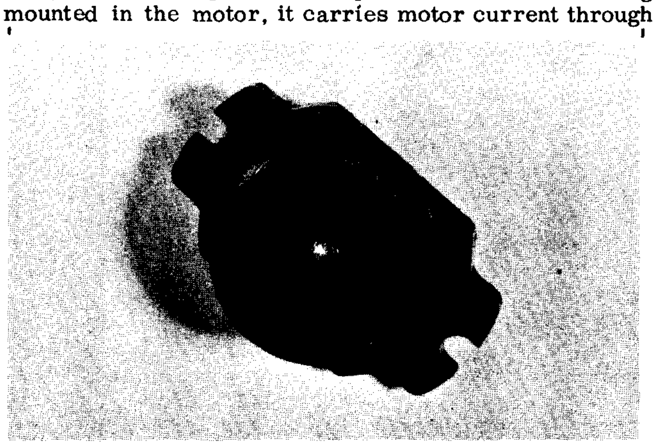

FIG. 4 "Klixon" Over-heat Protector

An "internal motor protector" whose use in oil field motors is increasing, is the "Rod and Tube Anticipating Thermal Sensor". See Fig. 5. This device works on the "bimetallic" principle as do the thermostat and the Klixon. However, instead of using a bimetallic disc, it consists of a rod inside a tube. The metals are selected so that the tubes' thermal expansion coefficient is much greater than that of the rod. A switch is actuated in the assembly when the temperature of the outside tube reaches a preset figure. On slow heating the temperature of the rod and the tube increase at the same rate so there is little difference in expansion between the two parts. When the rate of rise is rapid,

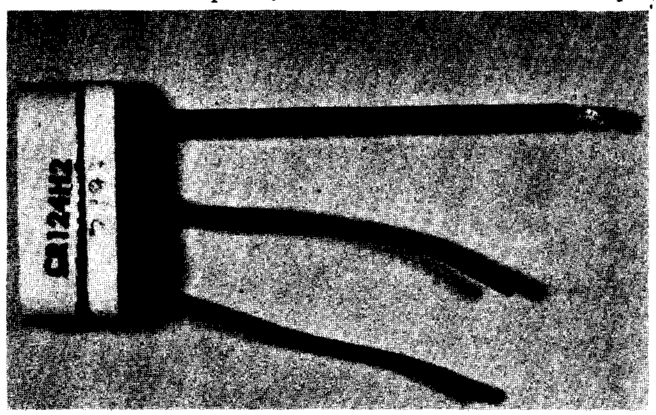

FIG. 5 Rod and Tube Anticipating Thermal Sensor

the tube expands at a much faster rate than the rod and thereby causes the switch to open at a lower than normal temperature. Thus, the device anticipates the rapid rate of temperature rise. The rod and tube assembly is mounted in the stator winding end turns. There are presently two rod and tube devices on the market, Spencer's "2 TM Thermal Protector" and General Electric's "Thermotector".

It should be noted that the rod and tube devices are solely responsive to heat. The leads of the device are connected into the holding coil circuit of a magnetic starter. Opening of the switch in the device drop out the magnetic starter and prevents further overheating and possible winding burnout. One limitation of the rod and tube device is found on so-called "rotor-limited" motors. Where high reversing duty, frequent cycling, or high torque-high slip motors are involved, it is desirable to use a high resistance rotor in the motor. In such motors, the temperature in the rotor rises at a very much faster rate under locked rotor or stall conditions than the temperature in the stator windings; and therefore, the rotor may reach damaging temperatures before the winding temperature is critical. Many present day oil well pumping motors fit this category. In such cases, an overload relay in the control circuit should be used also to sense the motor current and shut off the power prior to rotor failure.

Another "internal motor protector" is the Thermistor. This device is also a temperature responsive sensor, but has several differences from the rod and tube sensor. See Fig. 6. In the Thermistor system (Westinghouse's Guardistor is an example) small ceramic disc are embedded in the coil windings. These discs have either a negative or positive temperature coefficient of resistance, and the resistance remains at a fixed value at normal operating temperatures. The resistance changes very rapidly when unsafe temperatures are reached. This change in resistance causes the circuit to operate and disconnect power from the motor. A disadvantage of the Thermistor type of protector is the complicated and expensive power source and control circuit associated with it. Also, the Thermistor has the same limitation as the rod and tube device when used with rotor-limited motors. As with the rod and tube device, overload relays should also be used in the control circuit to gain more complete protection.

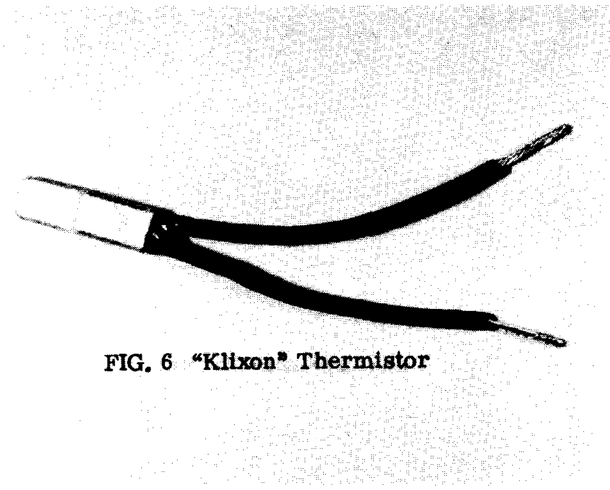

FIG. 6 "Klixon" Thermistor

From the foregoing, it is concluded that the ultimate in protection of oil well pumping motors would include overload relays in the magnetic starter enclosure and either rod and tube or Thermistor protectors within the motor. One further point should be noted and that is the requirement of the National Electric Code for branch circuit protection. This has historically meant overload relays in the starter. In some areas, adherence to the code will be required.

If you are using larger form-wound motors for water-flood injection pumps or pipeline pumps, the rod and tube or Thermistor is unsatisfactory since it is not practical to bury the devices in the winding. Added protection for these motors against single-phasing and unbalanced voltage can be obtained with a phase failure relay. The phase failure relay is a device that monitors the current in each phase of the electric line connected to the motor. If the current becomes unbalanced, the power circuit is disconnected. This device is generally considered too expensive for use on oil well pumping motors.