REDUCING ELECTRICITY COST IN THE OIL FIELD

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There are several ways that power consumers with large distribution systems can reduce their electrical cost. In this paper we will discuss two methods. The first method will be the application of capacitors and the second is the selection of the proper rate.

Basic Function Of A Capacitor

Let's start off by looking at some basic facts concerning electricity. First, current flowing through a wire causes a loss of power that can be calculated by squaring the current and multiplying it by the resistance* of the wire ($P = I^2R$). Second , as current flows through the wire it causes a voltage drop that is calculated by using the formula $V = I \times R$ where I is the current in the wire and R is the resistance of the wire. By examining both formulas we can see that the reduction of current is the key to the reduction of both losses and voltage drop in the system.

*Note: The use of resistance (R) throughout the paper does not accurately reflect the true operating conditions of a distribution system. The impedance values of a conductor or motor consists of a resistive value (R) plus a reactive value (X) and should be considered when analyzing the distribution system. However, in order to easily convey the general results of the analysis, the reactive values were considered negligible.

Now let's talk about the power loss in a wire. First, it is lost int the form of heat. Secondly, someone pays for it. If it is on the power company's side, we bear the cost.

Is there a way of reducing this power loss? The answer is yes. We could simply reduce the resistance of the wire by putting in larger wire. Or, we can reduce the current. The current can be reduced in at least two ways. One is by reducing the load, but that doesn't help your oil production. The other way is by adding capacitors. But, how does the installation of capacitors reduce the current?

First we need to understand the composition of the current. Let's look at the simple circuit in Figure 1. The total current flowing in the circuit is composed of both real current and reactive current to run. The real current does the work while the reactive current builds the magnetic fields around the windings of the motor. Both real current and reactive current create real power loss in the conductors in the form of watts. Now the real current can only be reduced slightly and this is due to increasing the voltage at the motors. But the flow of reactive current on the wires can be significantly reduced or even eliminated by the use of capacitors.

Let's look at the same circuit but this time let's install a properly sized capacitor bank near the substation. (See Figure 2) Notice that the capacitor is now supplying the reactive current for the motor instead of the reactive between the substation and the capacitor and the (I^2R) power loss in those wires has been reduced since the current has been reduced.

But, the current between the capacitor and the primary meter and between the primary meter and the motor remains unchanged. So, the power loss in those wires remains the same.

If the capacitor is sized properly and placed near the primary meter (PME), the electric company's (I^2R) losses, in the form of watts, will be minimized. (See Figure 3.) Except for the slight decrease in real current due to increased voltage at the PME, the oil company hasn't gained anything from the capacitor installation at the PME. Now this often happens when we, the electric company, install capacitors on our side of the meter and the oil company doesn't install and capacitors. We reduce our losses significantly and the oil company doesn't reduce its losses.

Let's look at the ultimate system. (See Figure 4.) Here we have a system where the properly sized capacitors are placed very near the motors. As you can see, the electric company still realizes its savings. But now the oil company enjoys a savings too, since the current flowing in the oil company wire has been reduced,thus reducing the I^2R losses (KW). Not only does the oil company realize real savings in the form of reduced electric bills, but there will be higher voltage at the motors which will increase the life of the motors and reduce maintenance costs. Often by reducing the current on overload wire, the motors which will increase the size of the wire will be eliminated. As a matter of fact, if the conductor in a system is loaded to 100% capacity it would be possible to install additional load on the system by simply installing capacitors.

Load Flow Study Of A Large Distribution System

Shown on Figure 5 is a one-line schematic of a 3 phase, 12.5 kv distribution system. The system covers approximately 16 sections, supplies a load of 8,000 kw, and is composed of 18 miles of 3 phase primary conductor. We have put all of this data into a load flow program in order to calculate the voltage at various points throughout the field, the current flowing in each section of the system, and the power losses throughout the entire system.

As you can see in Figure 5, the voltages (480 V base) are extremely low and totally unacceptable. Often, an oil company will try to solve this low voltage problem by buying transformers with voltage taps and setting these taps so that the secondary voltage is in an acceptable range. This is actually not correcting the problem, but only correcting a symptom of the problem. A transformer change-out program could be as expensive as the installation of capacitors. Now, in our case the voltage in the end of the feeder is so low that transformers with taps will not help.

By running a load flow program, we have detected another problem besides low voltage. In three sections of this system the primary conductor is overloaded. Shown in Figure 6 are the three overloaded sections (9-12, 21-24, and 24-25). The rating of 336 MCM aluminum is 442 Amps and 4ACSR is 122 Amps. So there appears to be no choice except reconductor these three sections.

With this reconductoring accomplished, another load flow program was run. The I^2R losses in the system are reduced by 97 kw for a total annual savings of approximately $33,000 (See Figure 7). As you can see from Figure 7, the reconductoring raised the voltage at several points in the system. Often reconductoring is done only to solve overloading problems, but in this case we reduced losses, improved the voltage and solved the overloading problem. Of course the voltage is still unacceptably low.

In Figure 8 we have the same system with the reconductoring completed and TU Electric capacitor banks installed on the TU side of the primary metering equipment (PME). Again another load flow program was run. As you can see, the voltage has again been improved and the losses reduced by 201 kw for a total savings of approximately $70,000 annually.

This kw savings on the oil side of the meter resulted from an increase in voltage throughout the field and thus a decrease in real current. A decrease in the real current low on the oil company's primary system resulted in less I^2R losses in the wire. But the voltage out in the oil field is still low even though the voltage at the PME is 486 volts. Still, distribution transformers with taps are not the answer since the taps can only raise the voltage by 10%.

Now, lets look at the real solution to this problem. In Figure 9 the oil company has placed capacitors throughout the field. Using a load flow program, these capacitors can be properly placed and sized. As you can see, the low voltage problem has been eliminated. The I^2R losses on the customer side of the PME have again been reduced from 895 kw, the initial losses to 229 kw, for a total reduction of 666 kw. This translates into an annual savings of approximately $230,000.

The cost of installing these capacitors is approximately $80,000. This makes a relatively fast pay back.
Capacitor Appication Summary

So capacitors installed on an oil company's distribution system can solve several problems. This will increase the life of the motors in the field and reduce field maintenance cost. Second, the I^2R loss can be reduced, caving the oil company money every year in reduced electrical costs. But one thing that is often overlooked is the fact that the current throughout the primary distribution system has been reduced dramatically allowing additional loads to be supplied in the lease without having to spend money in costly reconductoring. (See Figure 10)

At this point the question should be asked about the three sections we reconductored (9-12, 21-24, 24-25) and the KW savings due to that reconductoring. First we can see that based on the reduced current levels the original conductor in those three sections would not have been overlooked after the capacitors were added. Second, without the reconductoring and by placing capacitors throughout the field the kw losses in the field could be reduced by 638 kw or approximately $220,000 annually (See Figure 11). That's only $10,000 less than the amount saved in Figure 8 with the three sections reconductored. It is very doubtful that the reconductoring of the three sections can be justified economically. So before an oil company makes the decision to reconductor a field; the current reductions, due to adding capacitors, should be investigated.

I'm sure that many of your companies have engineers on their staff that can properly size and place capacitors in a field. But, if your organization does not have these capabilities and you have a possible application I would recommend that you search out an engineering firm that has that expertise.

Rates

Let's take a look at rates and the advantage of some rates over others. Of course there are some qualifications that are required for these rates. Listed below is a brief description of each rate:

1. Rate G (General Service Rate) - This is applicable to any customer served at one point of delivery and measured through one meter. TU provides transformers and any primary voltage extensions.
2. Rate GP (General Service Rate with Primary Service Credit) - Primary Service Credit on the General Service Rate G is available to customers when service is provided at the most available primary distribution voltage and the customer owns the distribution line and transformers.
3. Rate HV (High Voltage Service Rate) - This rate is applicable to any customer contraction for electric service (not less than 5,000 kw) at transmission voltage at one point of delivery and measured through one meter.
4. Rider I (Interruptible Service) - This interruptible service is applicable in conjunction with the General Service Rate

with, General Service Rate with Primary Service Credit and the High Voltage Service Rate to any customer who has 5,000 kw or more of separately metered and controlled interruptible load.

Shown in example 1 is a customer that had 10 separate accounts on rate G combined into one GP rate account. Each general service account represented one oil well pumping unit. In this study the total demand (kw) of the 10 individual accounts was reduced by 10% due to demand diversification. For the customer to combine these accounts may require that he construct additional primary lines and/or reconductor existing primary lines. In this specific case the customer would save approximately $13,000 annually.

Shown in example 2 is a customer that is on the GP rate but is considering building or purchasing a substation and switching to the HV rate. Now the customer's supply voltage must be 69kv, phase to phase, of greater. In this case the customer would save approximately $258,000 annually. Of course the cost of building or purchasing the substation must be considered before making such a decision.

Shown in example 3 is a customer that was receiving service at the HV rate and switched to the HV rate with the interruptible service rider. TU Electric installed all of the equipment necessary to interrupt the interruptible load. This equipment is under the exclusive control of the company and was installed at the expense of the customer. Some firm power may be retained by the customer. The customer shown in example 3 could realize an approximate annual savings of $605,000.

According to the Tariff for Electric Service, an interruptible customer can be interrupted up to 400 hours per year but no more than 12 hours during a 24 hour period. The actual annual down time for interruptible customers over the past 6 years has been 8 to 16 hours yearly. Interruptible service customers can be interrupted in two ways:

1. If the system frequency drops below 59.7 cycles, an underfrequency relay will interrupt the customer's interruptible load.
2. If the system has generation problems the TU system operator can interrupt this customer's interruptible load via telephone data circuit.

Shown in Example 4 is the 12 month bill of a customer on the GP rate. As you can see the last 12 month bill was $1,699,624.94. This customer made the decision to take advantage of interruptible service. Shown in example 5 is the 12 month bill of $1,308,420.70 for the same customer on the interruptible rate. The annual savings for this customer is $391,204.24. The interruption that this customer experiences will be very similar to the interruptions of the HV customer mentioned in example 2.

Example 1
Annual Billing Estimate
Rate GP - 300

TU CUSTOMER — MIDLAND COUNTY
FUEL COST: 0.021545 — POWER COST RECOVERY FACTOR 0.001548

CONTRACT KW: 188

MONTH	KW DEMAND	BILL KW	KWH USE	BILL AMT	LF %	AVG COST
JANUARY	147	138	95026	3802.94	89.78	4.001
FEBRUARY	152	139	84031	3493.33	76.78	4.157
MARCH	142	137	77258	3284.36	75.56	4.251
APRIL	133	133	85346	3489.31	89.12	4.088
MAY	141	137	77689	3296.77	76.52	4.243
JUNE	134	134	79356	3323.83	82.25	4.188
JULY	131	131	81203	3356.06	86.09	4.132
AUGUST	135	135	71449	3103.14	73.5	4.343
SEPTEMBER	135	135	83421	3447.85	85.82	4.133
OCTOBER	139	136	77985	3298.32	77.92	4.229
NOVEMBER	133	133	84669	3469.82	88.41	4.098
DECEMBER	144	137	86729	3557.06	83.65	4.101
MAX KW	152		984162	40922.79	73.91	4.158

THIS ENERGY PROFILE IS COMPLIED FROM 10 EXISTING ACCOUNTS.
DEMAND DIVERSITY OF 10 HAS BEEN APPLIED FOR TOTAL DEMAND
ENERGY USE INCLUDES TRANSFORMER LOSS ADJUSTMENT OF 1.0 %
FOR INDIVIDUAL ACCOUNTS SERVED AT SECONDARY VOLTAGE.
FUEL ADJUSTMENT USED IN THESE CALCULATIONS: 0.021545
POWER COST RECOVERY FACTOR USED : 0.001548

10 ACCOUNTS– INDIVIDUAL METERS	$54,218.11
10 ACCOUNTS– ONE PRIMARY METER	$40,922.79
YEARLY SAVINGS	$13,295.32

Example 2
Comparison of Billing Between Rate GP and Rate HV

TU CUSTOMER

THE PRESENT RATE IS 300
THE PRESENT CONTRACT KW IS 12500

RATE HV ENERGY USE IS ADJUSTED TO REFLECT TRANSFORMER LOSSES 0.06%

MO	KW DEM	KWH	300 RATE GP $	ADJ KW	ADJ KWH	400 RATE HV	SAVINGS HV – GP $
9	8010	5563780	216219.2	8074	5608290	195685.41	20533.8
8	7679	4870050	195330.1	7942	4909010	175990.4	19339.72
7	7905	5279250	207293.7	7968	5321484	187338.45	19955.28
6	8635	5778080	226752.7	8704	5821484	204827.45	21925.22
5	8729	5353240	215176.5	8798	5396065	193673.63	21502.83
4	8536	5567400	219995.4	8604	5611939	198535.31	21460.13
3	8471	5828050	227046.6	8538	5874674	205335.22	21711.35
2	8692	5478020	218511	8761	5521844	196900.9	21610.06
1	8897	6364030	245452.9	8968	6414942	222254.1	23198.84
D	8817	5975020	233693.7	8887	6022820	211173.88	22519.83
N	8772	5456060	218437.2	8842	5499708	196719.54	21717.61
O	9025	6024970	236584	9097	6073169	213632.51	22951.45
			2660493			2402066.8	
THE DIFFERENCE IN 12 MONTH BILLING GP VS HP						$	258426.1

FUEL ADJUSTMENTS USED IN THESE CALCULATIONS — RATE GP 0.021545, RATE HV 0.020993

PCR FACTORS USED IN THESE CALCULATIONS — RATE GP 0.001548, RATE HV 0.000992

RATE HV INCLUDES TRANSFORMER LOSS ADJUSTMENT OF 0.8% ON KW
0.8% ON KW AND KWH FOR SECONDARY VOLTAGE METERING EQUIPMENT INSTALLATION

YEARLY SAVINGS WITH CUSTOMER OWNED SUBSTATION $258,426.12

Example 3
Annual Billing Estimate

RATE HV/ RIDER I – 450

CONTRACT KW: (MASTER METER) 15000 (FIRM POWER) 0
FUEL COST: 0.020993 — POWER COST RECOVERY FACTOR: 0.001000

MONTH	KW MAST	KWH FIRM	OP–KW KW	BILL KW	KWH MAST	KWH FIRM	BILL AMOUNT	LF %
JANUARY	13496	0	0	8074	9178400	0	261192.33	94.45
FEBRUARY	13664	0	0	7942	9480800	0	269113.09	96.36
MARCH	13664	0	0	7968	8607200	0	246230.88	87.48
APRIL	13384	0	0	8704	8803200	0	251364.71	91.35
MAY	13552	0	0	8798	8898400	0	253858.29	91.19
JUNE	13552	0	0	8604	9581600	0	271753.34	98.19
JULY	13776	0	0	8538	8948800	0	255178.41	90.22
AUGUST	13832	0	0	8761	9027200	0	257231.94	90.64
SEPTEMBER	13720	0	0	8968	9990400	0	282461.04	101.13
OCTOBER	13888	0	0	8887	8836800	0	252244.80	88.37
NOVEMBER	13496	0	0	8842	8629600	0	246817.61	88.80
DECEMBER	13664	0	0	9097	10662400	0	300062.74	108.37

TOTAL ENERGY COST RATE HV, RIDER I:	$3147509.18
TOTAL ENERGY COST, PRESENT RATE:	$3753046.68
COST FIFFERENCE: (RIDER I)	$605537.50

Example 4

A/KW	B/KW	KWH	ELEC–FUEL–TAX
5,368	5,368	3,540,291	$142,812.65
5,396	5,396	4,166,182	$160,746.16
5,524	5,438	4,109,037	$155,264.12
5,421	5,412	3,546,531	$139,326.09
5,292	5,292	3,499,181	$136,591.63
5,409	5,409	3,629,597	$143,074.85
5,248	5,248	3,719,974	$143,848.99
5,164	5,164	3,508,960	$134,572.68
5,118	5,118	3,496,611	$136,125.54
5,146	5,019	3,610,678	$137,612.17
5,146	5,019	3,482,678	$134,042.22
5,191	5,030	3,422,701	$131,888.69
5,228	5,039	3,416,099	$132,923.10
LAST 17 MONTHS BILLING			$1,699,624.94

Example 5
Annual Billing Estimate

RATE HV/ RIDER I – 350

CONTRACT KW: (MASTER METER) 5524 (FIRM POWER) 0
FUEL COST: 0.021545 POWER COST RECOVERY FACTOR: 0.002248

MONTH	KW MAST	KWH FIRM	OP–KW KW	BILL KW	KWH MAST	KWH FIRM	BILL AMOUNT	LF %
JANUARY	5396	0	0	1381	4186182	0	123251.87	107.2
				BASE BILL AMOUNT:			33491.48	
				PCR COST (0.002248)			0.00	
				FUEL COST (0.021545)			89760.39	
FEBRUARY	5368	0	0	1381	3540291	0	106199.46	91.5
				BASE FUEL AMOUNT:			29923.90	
				PCR COST (0.002248)			0.00	
				FUEL COST (0.021545)			76275.56	
MARCH	5030	0	0	1381	3422701	0	102995.73	94.5
				BASE BILL AMOUNT:			29253.64	
				PCR COST (0.002248)			0.00	
				FUEL COST (0.021545)			73742.09	
APRIL	5019	0	0	1381	3482678	0	104629.80	96.3
				BASE FUEL AMOUNT:			29595.51	
				PCR COST (0.002248)			0.00	
				FUEL COST (0.021545)			75034.29	
MAY	5019	0	0	1381	3610678	0	108117.16	99.9
				BASE BILL AMOUNT:			30325.11	
				PCR COST (0.002248)			0.00	
				FUEL COST (0.021545)			75334.48	
JUNE	5118	0	0	1381	3496611	0	105009.41	94.8
				BASE FUEL AMOUNT:			29674.93	
				PCR COST (0.002248)			0.00	
				FUEL COST (0.021545)			75334.48	
JULY	5164	0	0	1381	3508960	0	105345.86	94.3
				BASE BILL AMOUNT:			29745.32	
				PCR COST (0.002248)			0.00	
				FUEL COST (0.021545)			75600.54	
AUGUST	5248	0	0	1381	3719974	0	111094.93	98.4
				BASE FUEL AMOUNT:			30948.10	
				PCR COST (0.002248)			0.00	
				FUEL COST (0.021545)			80146.83	
SEPTEMBER	5409	0	0	1381	3629597	0	108632.61	93.1
				BASE BILL AMOUNT:			30432.95	
				PCR COST (0.002248)			0.00	
				FUEL COST (0.021545)			78199.66	
OCTOBER	5292	0	0	1381	3499181	0	105079.43	91.6
				BASE FUEL AMOUNT:			29689.58	
				PCR COST (0.002248)			0.00	
				FUEL COST (0.021545)			75389.85	
NOVEMBER	5412	0	0	1381	3546531	0	106369.48	91.0
				BASE BILL AMOUNT:			29959.47	
				PCR COST (0.002248)			0.00	
				FUEL COST (0.021545)			76410.01	
DECEMBER	5438	0	0	1381	4109037	0	121694.96	104.9
				BASE FUEL AMOUNT:			33165.76	
				PCR COST (0.002248)			0.00	
				FUEL COST (0.021545)			88529.20	
TOTALS					43732421		1308420.7	

LAST 12 MONTHS ACTUAL BILLING	$1,699,624.94
LAST 12 MONTHS BILLED ON INTERRUPTIBLE SERVICE	$1,308,420.70

YEAR SAVIINGS	$391,204.24

Exhibit # 3
Monthly Load Interruptions Report
January 1990

CUSTOMER	DATE	ELAPSED TIME	RELAY OPER.	REQUEST OPER.	FREQUENCY AT TIME	UNIT CAUSING INTERRUPTION	LAST TWELVE MO. NO. OF EVENTS RELAY	LAST TWELVE MO. NO. OF EVENTS REQUEST	LAST TWELVE MO. TOTAL ELAPSED (HOURS)
							26	3	15:16
#1							27	4	12:45
#2							25	3	15:40
#3							26	2	16:25
#4							19	2	11:05
#5							4	2	8:20
#6							26	3	16:48
#7							26	3	14:33
#8							23	3	15:43
#9							25	3	16:39
#10							7	2	9:14
#11							17	3	12:01
#12							19	2	10:46
#13							26	2	16:25
#14							4	2	8:14
#15							0	0	0:00
#16							26	3	15:40
#17							26	2	12:31
#18							26	2	16:32
#19							25	3	14:39
#20									

THERE WERE NO INTERRUPTIBLE EVENTS DURRING JANUARY 1990

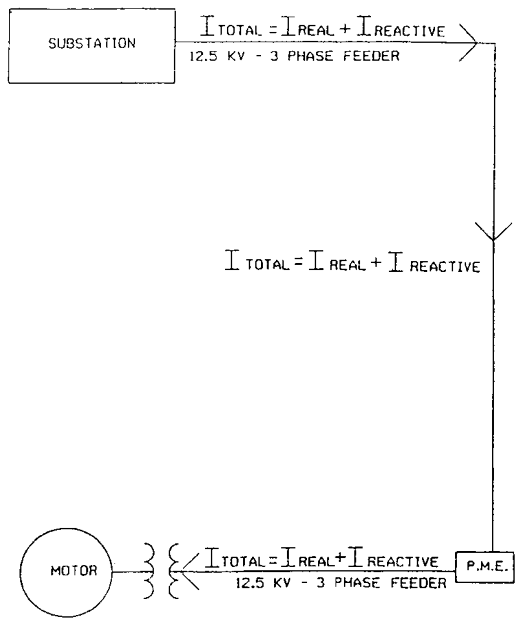

Figure 1

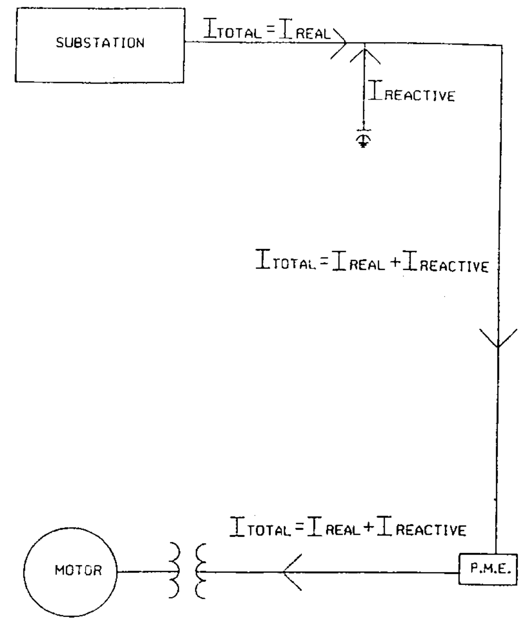

Figure 2

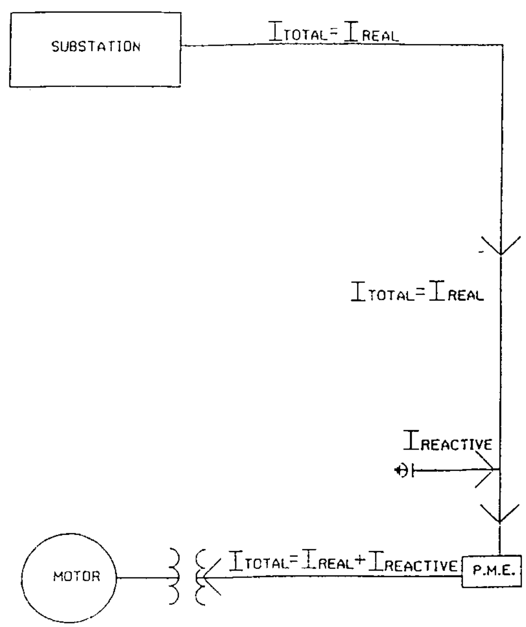

Figure 3

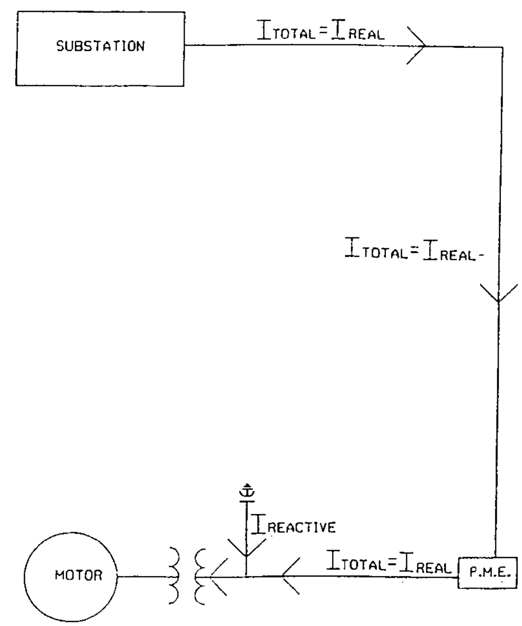

Figure 4

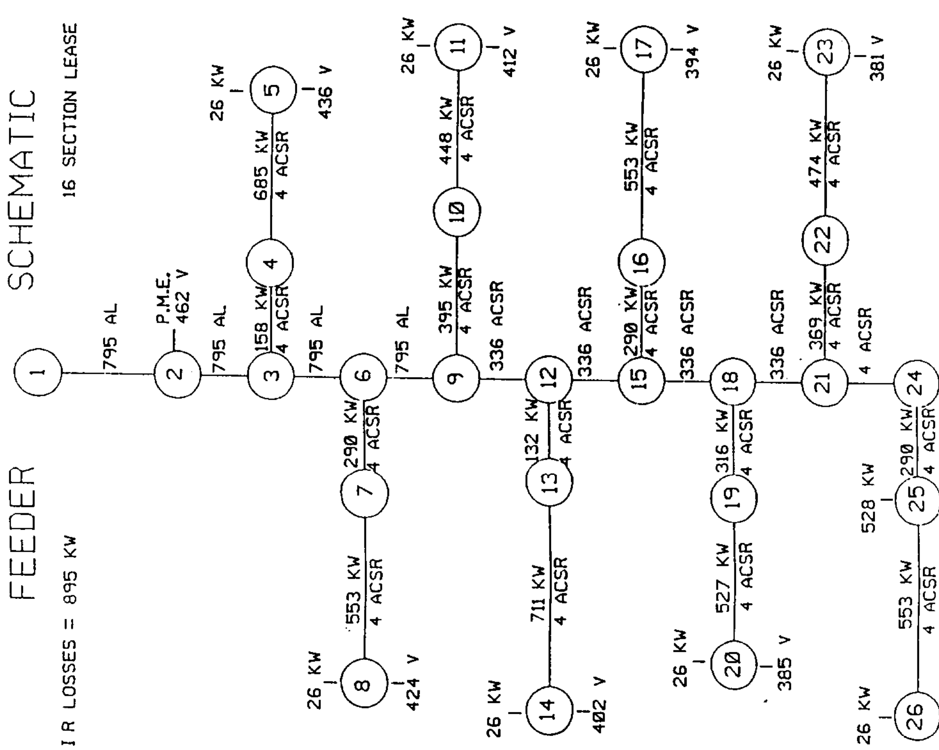

Figure 5

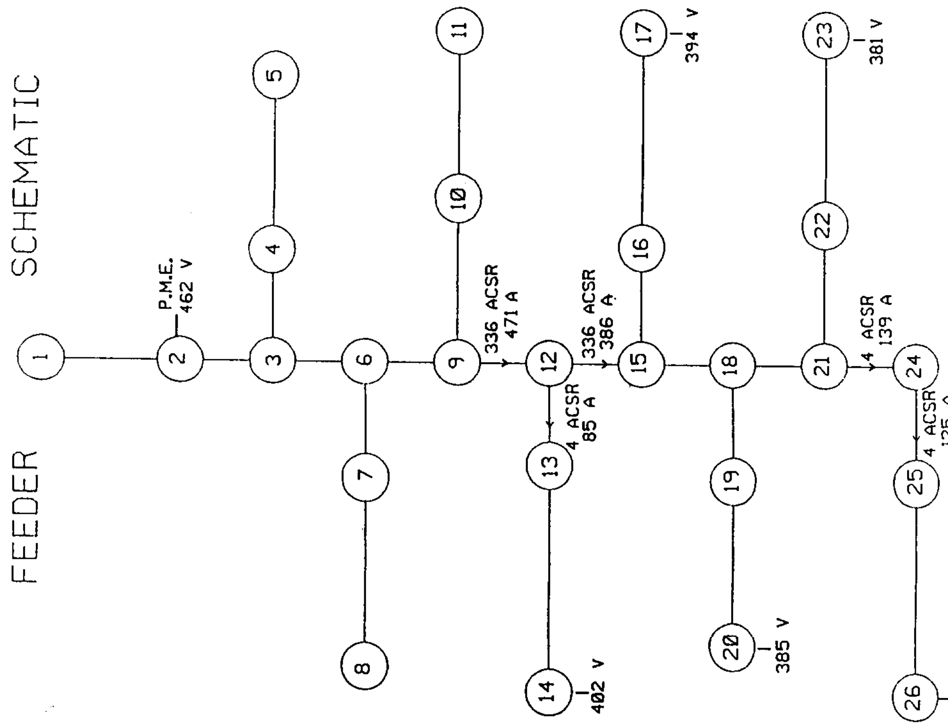

Figure 6

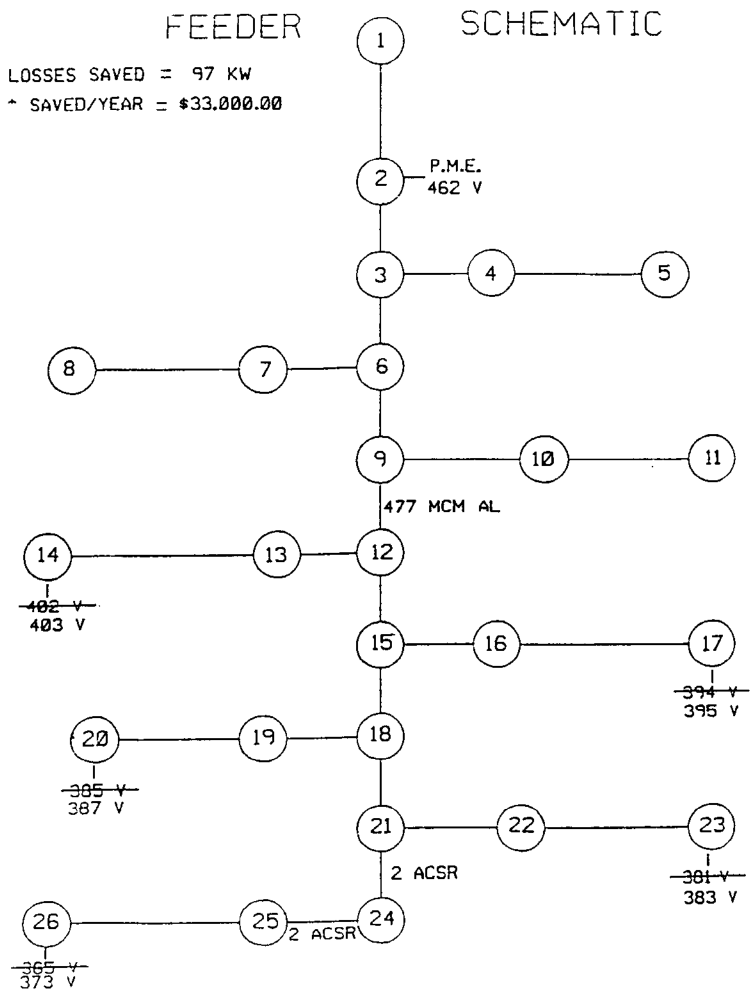

Figure 7

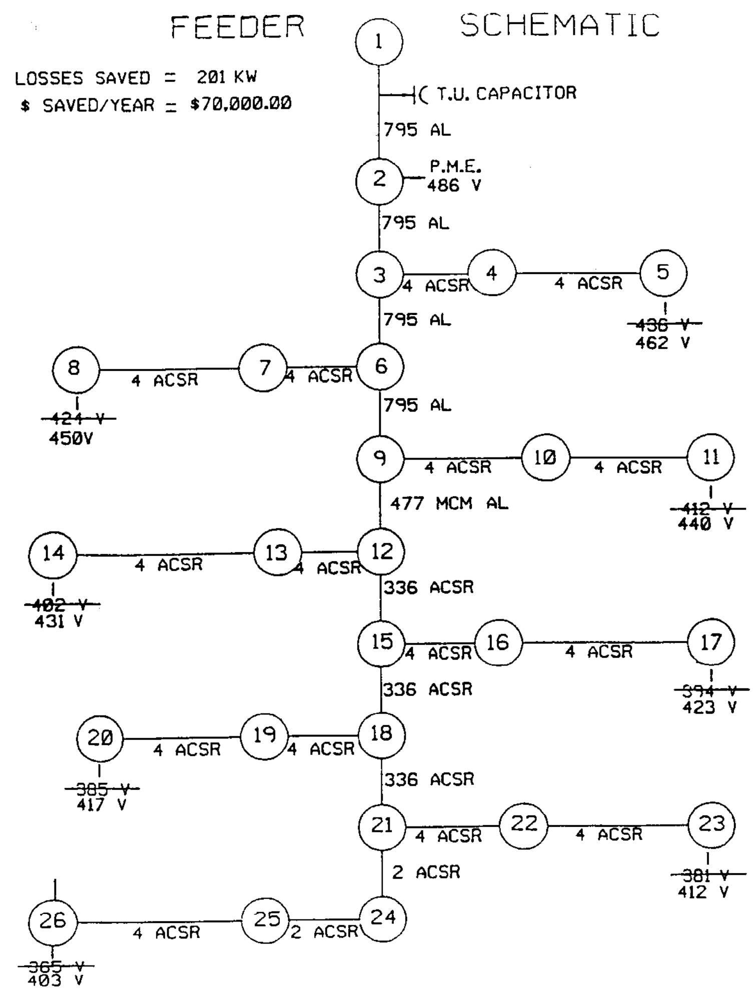

Figure 8

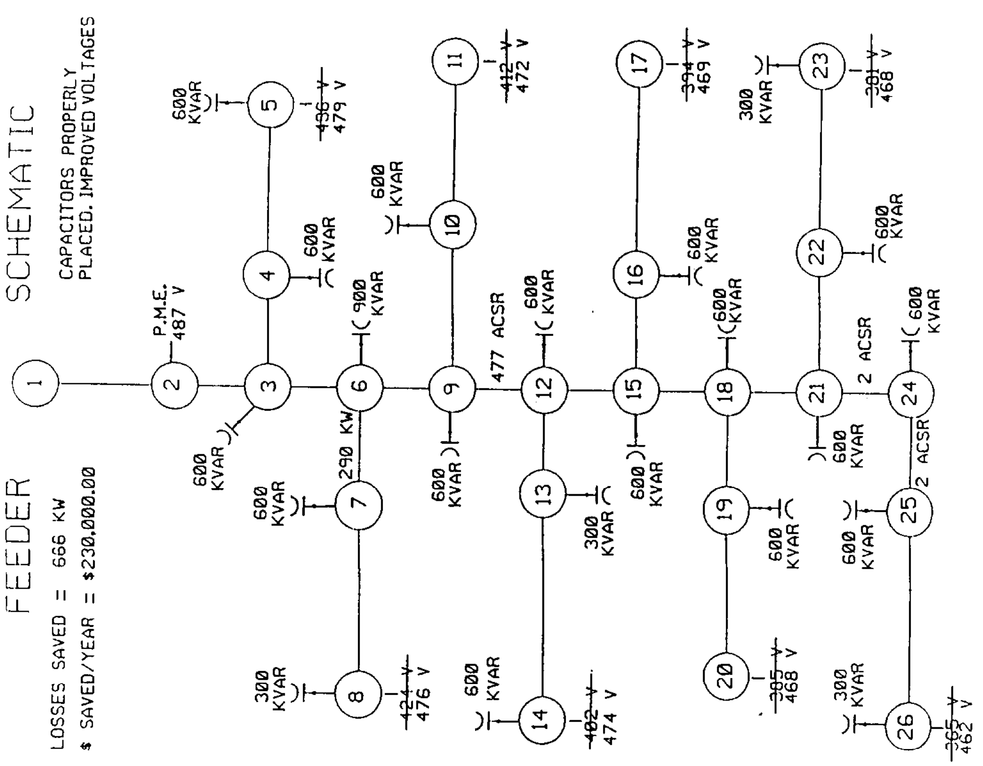

Figure 9

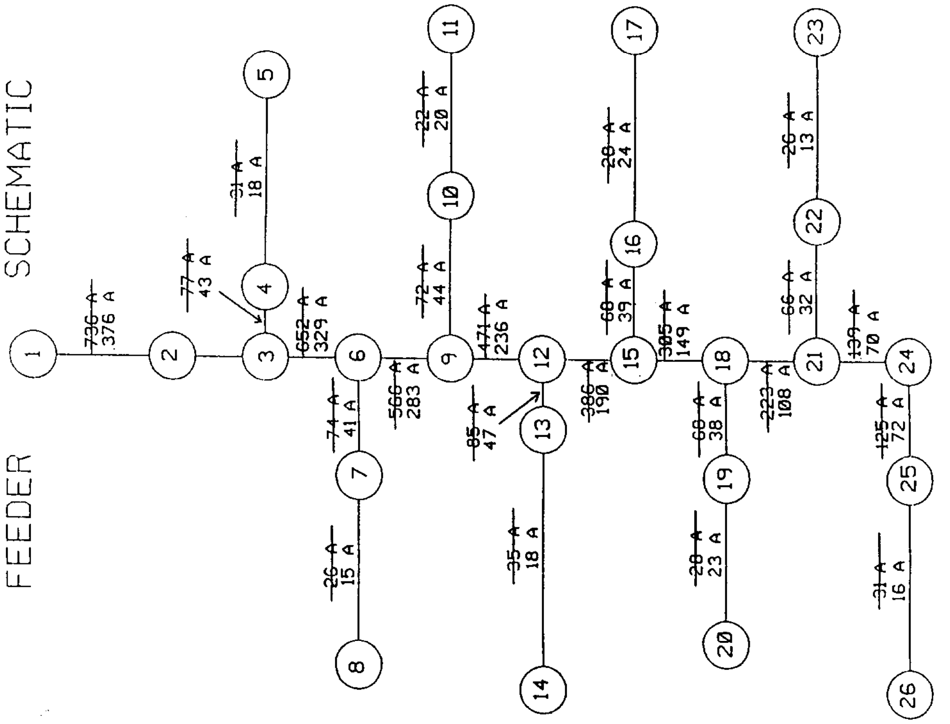

Figure 10

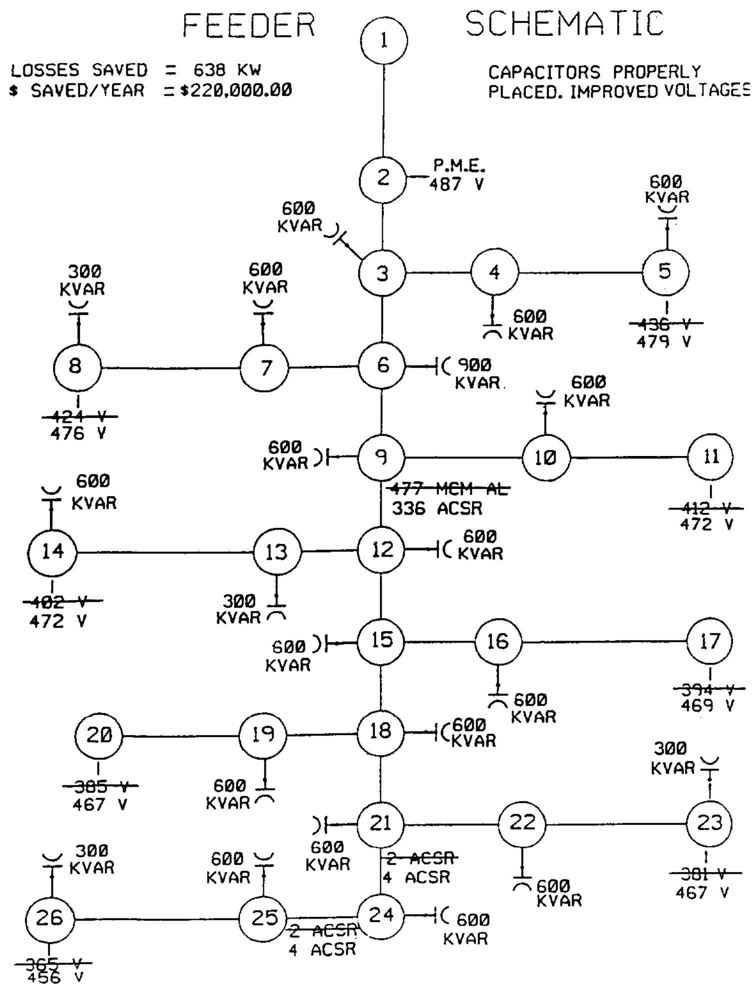
FEEDER SCHEMATIC
LOSSES SAVED = 638 KW
$ SAVED/YEAR = $220,000.00
CAPACITORS PROPERLY PLACED. IMPROVED VOLTAGES
P.M.E. 487 V
600 KVAR
300 KVAR
~~436 V~~ 479 V
900 KVAR
~~424 V~~ 476 V
~~477 MCM AL~~ 336 ACSR
~~412 V~~ 472 V
~~402 V~~ 472 V
~~394 V~~ 469 V
~~385 V~~ 467 V
~~2 ACSR~~ 4 ACSR
~~381 V~~ 467 V
~~365 V~~ 456 V

Figure 11