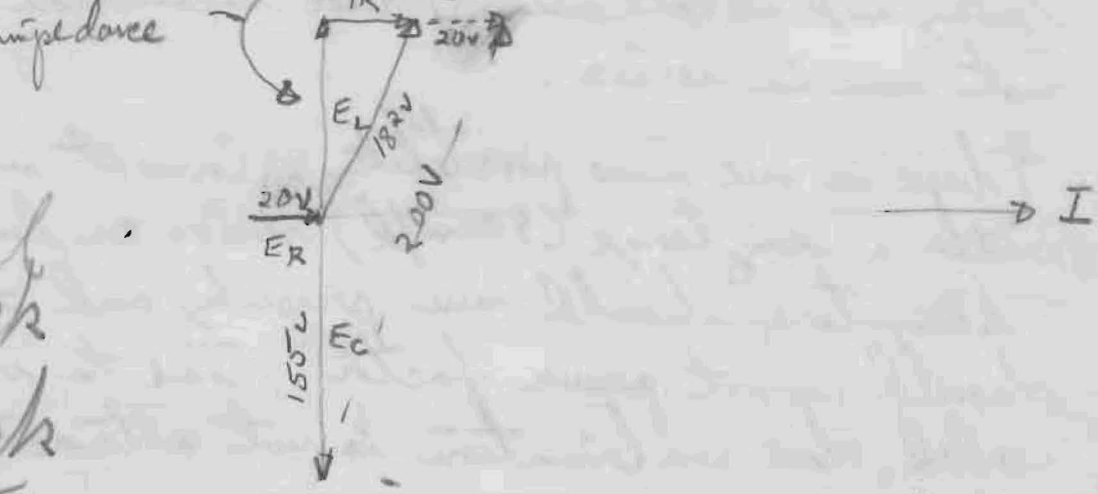
10-2-52

2 motors and 5 ohms plus 64 mfd in series. $X_C = 41.5\,\Omega$



switch off
208V Panel
182V Block
Switch on
200V Block
182V motors
155V condensers, $I = \frac{155}{41.5} = 3.74$ amps (too small)
20V resistors, $I = \frac{20}{5} = 4.00$ amps (too small)
System still capacitive, Turntable just creeps without getting up to full speed.

---

2 motors, 109 mfd in series, $X_C = 24.4\,\Omega$

switch off
208V Panel
182V Block
switch on
190V Block
250V motors
150V condensers $I = \frac{150}{24.4} = 6.2$ amps

Turntable runs jerkily as motors don't come up to speed properly and it creeps along. Apparently motors won't divide load evenly as hoped for.
Apparently what is needed is small wound rotor induction motors of high slip.

(over)

Took out condensers and operated motors in series across line, Turntable ran slightly better but still very jerky and uncertain, These induction motors will not run in series.

There is one more possibility, Connect motors in parallel with a very large (400 mfd) series condenser for resonance. The motors should run properly and the condensers should correct power factor. Due to very large condensers needed, this combination is not attractive.

What's really needed is four small 1/8 HP wound rotor induction motors of 2 pole design. They may be operated with high rotor resistance giving large slip, high torque and good power factor.

Best presently available combination is 2 motors in parallel, 5 Ω in series and 45 mfd across line.

10-2-52

First case,

$$(IR+20)^2 + (E_L+155)^2 = 200^2$$

$$IR^2 + E_L^2 = 182^2 \quad \text{or} \quad IR^2 = 182^2 - E_L^2 \quad \& \quad IR = (182^2 - E_L^2)^{1/2}$$

$$IR^2 + 40IR + 400 + E_L^2 + 310E_L + 24000 = 40000$$

$$182^2 - \cancel{E_L^2} + 40(182^2 - E_L^2)^{1/2} + 400 + \cancel{E_L^2} + 310E_L + 24000 = 40000$$

$$40(182^2 - E_L^2)^{1/2} = 40,000 - 24,000 - 182^2 - 400 - 310E_L$$

$$40(182^2 - E_L^2)^{1/2} = -(17,000 + 310E_L)$$

$$(182^2 - E_L^2)^{1/2} = -(425 + 7.75E_L)$$

$$182^2 - E_L^2 = 425^2 + 6600E_L + 60E_L^2$$

$$59E_L^2 + 6600E_L + 148,000 = 0$$

$$E_L^2 + 112E_L + 2510 = 0$$

$$E_L = \frac{-112 \pm (112^2 - 4 \cdot 2510)^{1/2}}{2} = \frac{-112 \pm 49.5}{2} = -81V$$

error somewhere in arithmetic

Second case

$$IR^2 + E_L^2 = 250^2$$

$$IR^2 + (E_L+150)^2 = 190^2$$

$$(E_L+150)^2 - E_L^2 = 190^2 - 250^2$$

$$\cancel{E_L^2} + 300E_L + 150^2 - \cancel{E_L^2} = 190^2 - 250^2$$

$$300E_L = 190^2 - 250^2 - 150^2$$

$$E_L = -\frac{48900}{300} = -163V \qquad X_L = \frac{163}{6.2} = 26.2\Omega$$

(system nearly in resonance) (condensers too large)

$$IR = (250^2 - 163^2)^{1/2} = (35900)^{1/2} = 189V, \quad R = \frac{189}{6.2} = 30.5\Omega$$

6-22-52

If four similar motors are used the inductive reactance per leg will be 26.5 x 2 = 53 ohms. The series resistance per leg will be 21.6 ohms. If condensers are used to tune out the reactance and a line voltage of 208 is used, then the current per leg will be 5.55 amps which is adequate for starting.

Capacity required for 53 ohms is 50 mfd

The voltage across condensers at start will be

$53 \times 5.55 = 294$ volts which is 416 peak

This is high but safe for 400V DC condensers.

If starting current is limited to 4.5 amps the peak voltage will be 336V

The impedance of motors will be 57.2 ohms in each leg

Voltage across motors terminals will be $57.2 \times 5.55 \times \sqrt{3} = 550V$

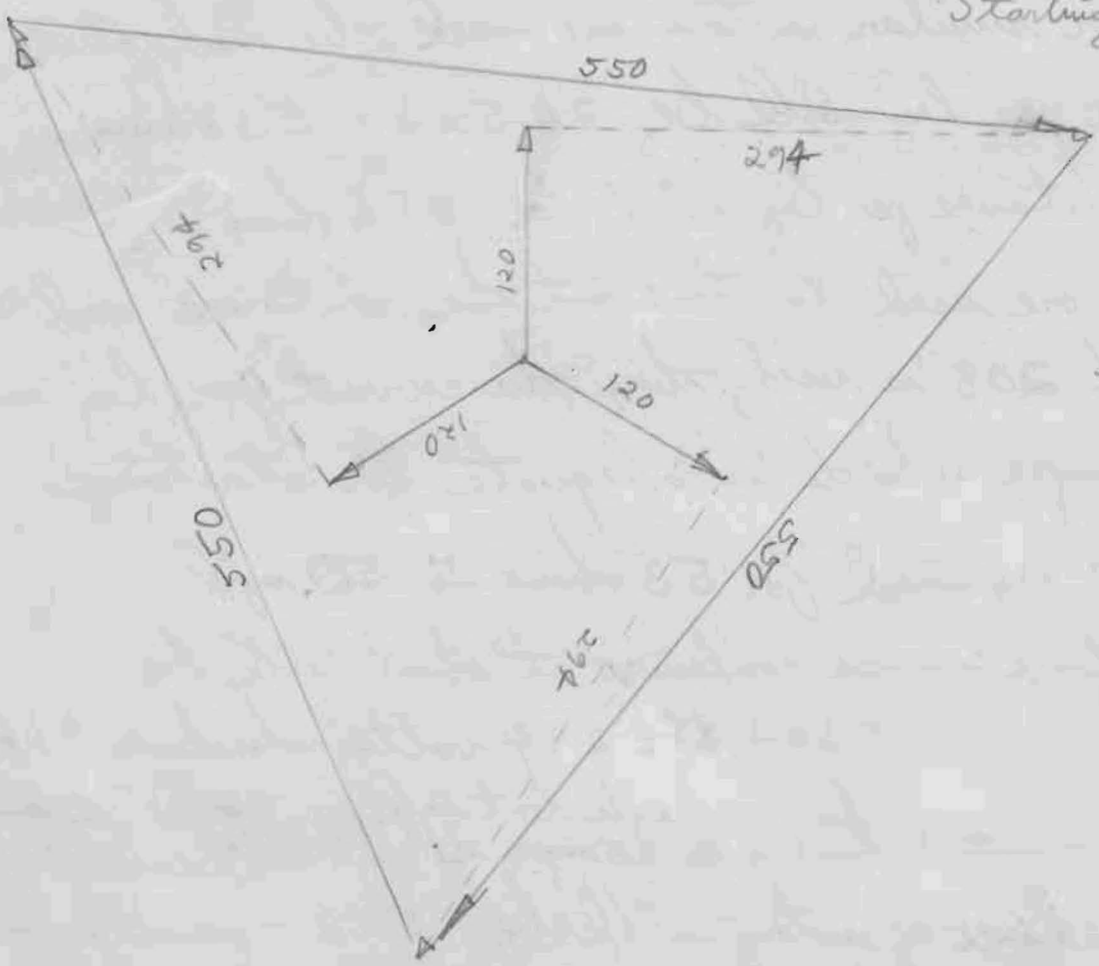
Each motor will have 550/4 = 137 volts to start which is ample. Series resistance may be added to reduce current if desired.

This scheme is even better as the turntable can be driven from all four corners. The starting current is adequate. No series resistors are needed and less capacity is required.

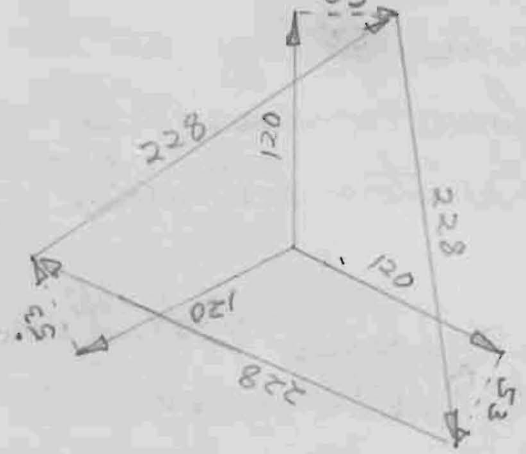
Running current about 1 amp. Voltage across condensers will be about 53 volts, Voltage across motor terminals will be $\sqrt{3}\,(120^2+53^2)^{1/2} = 228$ volts. This is 57 volts per motor which seems low, but may be adequate when motor is turning over at full speed as the turntable losses are very small and motor merely idles.

If motors are running one way and line voltage is quickly reversed the current thru + voltage across condensers will be double the starting value which may be quite small; More series resistance should be used.

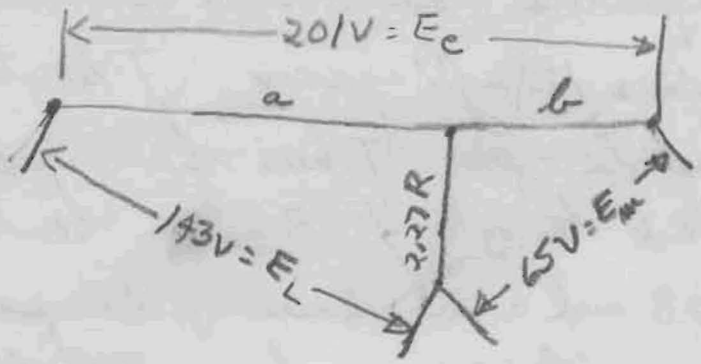
Starting condition



running condition



6-22-52



analysis of one leg.

✓ (1) $a + b = 201$, $a = 201 - b$

✓ (2) $a^2 + (2.27R)^2 = 143^2$

✓ (3) $b^2 + (2.27R)^2 = 65^2$

Eliminate $(2.27R)^2$ between (2) & (3)

✓ (4) $143^2 - a^2 = 65^2 - b^2$

Substitute a from (1) into (4).

✓ (5) $143^2 - (201-b)^2 = 65^2 - b^2$

Solve for b

(6) $143^2 - 201^2 + 402b - b^2 = 65^2 - b^2$

$402b = 65^2 + 201^2 - 143^2 = 24245$

$b = 24245/402 = 60.2$ volts, $X_L = \frac{60.2}{2.27} = 26.5$ ohms reactance of motor windings in series.

Solve for R from (3)

(7) $(2.27R)^2 = 65^2 - 60.2^2 = 600$

$R = (600)^{1/2}/2.27 = 10.8$ ohms.

This is a rough estimate as calculations of R are very sensitive to errors in voltage measurement. R should be measured next time motors are connected in series.

(over)

For series resonance the capacitors should have a reactance of 26.5 ohms. This requires 100 mfd approx. The total reactance of system will then be zero. Thus the current at starting will be limited to only E/R. If the line volts are maintained at 208 and a maximum of 6 amps is allowed the total series resistance per leg will be

$\left(\frac{208}{2 \cdot .866}\right)/6 = 20$ ohms. Thus the 11 ohms internal must be built up to 20 by adding series resistance.

at 6 amps thru 26.5 ohms the voltage across condenser bank will be 160 volts which is quite safe.

70 mfd more is required in each leg. a total of

$\frac{3 \times 70}{2} = 105$ more capacitors are needed.

When starting the load on alternator will be

$P = \sqrt{3} \cdot 208 \cdot 6 = 2160$ watts non reactive power.

Dissapation in series resistors will be

$P = 3 \cdot 6^2 \cdot 9 = 970$ watts

Heat loss in windings of each motor will be

$P = (2160 - 970)/2 = 1190/2 = 595$ watts

This is very high but is at start only.

Running current about 1 amp. Running copper losses will be

$P = \frac{3 \cdot 1^2 \cdot 11}{2} = 17$ watts in each motor

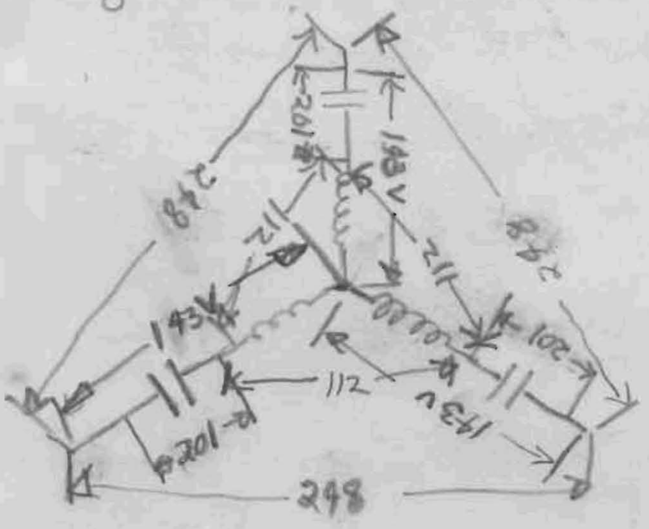
Voltage across motor terminals at start will be $E = \sqrt{3}\, I Z$

$Z = (26.5^2 + 10.8^2)^{1/2} = 28.6\,\Omega$, $E = 298$ volts or 149V per motor which is more than adequate.

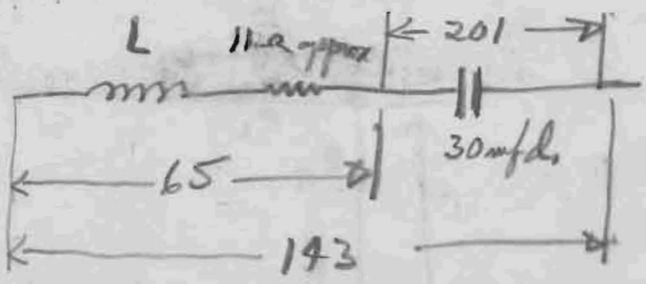
6-22-52

Analysis of combination with motors and condensers in series without extra 5 Ω resistors. Triumph Tester reads low by $\frac{230}{195}$. Corrected voltages are

Panel or line voltage = 230V without motors
Panel or line voltage = 248V with motors (stalled)
Voltage across motors = 112V (stalled)
Voltage across series condensers = 201 V



Overall Y



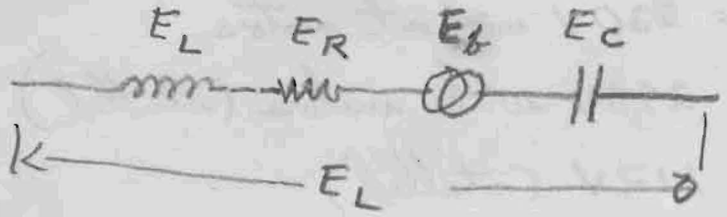
One leg

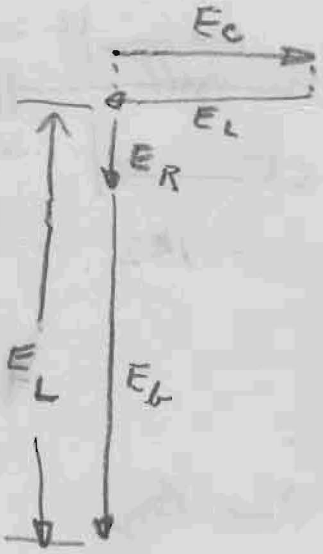
Reactance of condensers = $\frac{1}{2\pi fC} = \frac{1}{377 \cdot 30 \cdot 10^{-6}} = \frac{10^6}{11300} = 88.5\,\Omega$

Current in leg = $\frac{201}{88.5}$ = 2.27 amps. This is not enough to start the motors which require about 4.5 amps.

(over)

When motors are running a back EMF is developed which has a voltage in phase with the current and opposed thereto. This greatly reduces the current when operating.





In the stalled condition $E_b = 0$, so $E_R = E_L$ when $E_C = E_L$. Thus series resistance must be added to limit I to a safe and reasonable value.

This series resonant starting scheme is probably just as good as using wound rotor motors and a whole lot simpler as no mechanical work is needed, actually all four motors could be started in series this way

6-20-52

Connected motor on truck with eyebolts and opposite truck in series. Left 5 Ω and condensers. With 230 V on panel the triumph showed 195 V at fuses. Throwing on motor caused no line drop whatever, as motors came up to speed line rose to 215 at fuses and 250 at panel. Voltage at motors showed 210 which agrees with 5 volt measured drop across the 5 ohm resistors. System overcompensated.

With same line and condensers now in series with motors but no 5 ohm resistors, when motors switched on the line rose to 210V. Across motor 95V, across condensers 170 volts. Condensers still too small. The net load on line is capacitive. Motors won't start.

Used 8/15 of condensers in parallel again. No 5 Ω resistors. 208 V at panel, 188 V at fuses. Turn on motors still in series. First drops to 170 V, then rises to 195 V. & 220V at panel. System still over compensated.

Used 8/15 of condensers. Motors in parallel again. Put 5 Ω resistors back. 208 V at panel, 188 V at fuses. Turn on motors. Line first drops to 145 V & then rises to 188 V. Turn off motors no change in line. Thus system exactly compensated. 11 V drop across 5 Ω resistors running.
Left this way on 6-20-52

5-31-52

Corner with eyebolts. Motor is made by Kingston Connolley and secured from Hero electric in Paia. Is Y connected and has center leads brought out today

Motor in corner with stud bolts is a Howell. It is Y connected but only has one set of center leads brought out.

Motor in corner opposite eyebolts is a Deihl. It's probably Y connected but has center leads obscured and is all baked solid with varnish by HC+S.

Motor in corner opposite studbolts is a Marathon. Is probably Y connected but can't find center leads as all baked solid with varnish by HC+S. Trouble may be in this motor.

HC+S baked motors too hard so it is not safe to open up windings looking for center leads. If this were done all the insulation would break off and the motors would have to be rewound. I paid money to get this done! It sure gripes me.

When I left the turntable not in running order. Each motor should again be tested separately. Also extension has a short in female end. This was a day in reverse.

6-14-52

On corner with stud bolts and opposite corner took the pinion off shaft of speed reducer and disconnected motor leads at center. This leaves only two motors driving turntable from corner with eye bolts and opposite corner. Using condensers in box the system is overcompensated as running line volts higher than off line volts; The two motors take about 8 amps start and 2½ amps run. This includes condenser current and 5 ohms in series with each motor lead. The motors will start on about 80 volts. Thus two in series will probably start satisfactorily on full line volts.

Next disconnected the 5Ω resistors and rewired the condensers 30 mfd in each leg. Condensers too small as only 35 volts appears across motors. Motors wouldn't start. Larger condensers needed to pass more current or else wire motors in series.

Next took off condensers and placed motors directly across line without 5 Ω resistors. Reactive current so large voltage dropped below closing of relays which chattered. This is very bad combination. By holding relays in the motors would come up to speed. However the reactive current even when running depressed the line voltage. Line voltage rose 15 volts on removing motors.

About only remaining thing to try is putting motors in series plus maybe the condensers in series again.

What is really needed are four small 2 pole, 3 phase wound rotor motors. Put motors, resistors & condensers back like first paragraph.

Turntable performance 4-26-52

Line voltage at panel 230 on panel voltmeter
Line voltage at fuse block. 200 on triumph tester
5 ohms in series with each motor
Voltage drop across resistors running 23 volts
Motor current running 4 1/2 amps

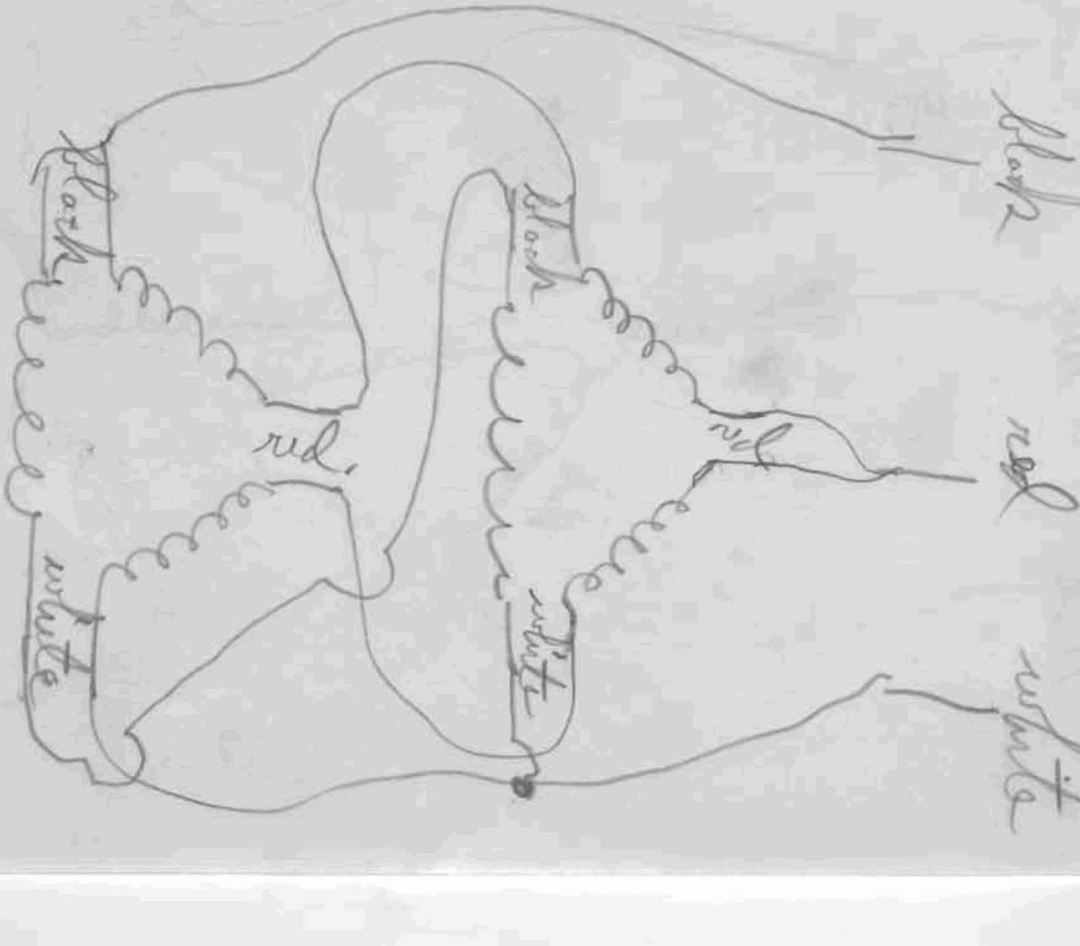
Voltage across motors at start 70 volts,
Drop across resistors at start 59 volts
Line current start 12 amps
Line voltage start 140 volts

The alternator is very sensitive to reactive loads. Putting on a 5 amp resistive load steady didn't help matters much. A 4 1/2 amp leading load will cause voltage to rise about 20 volts,

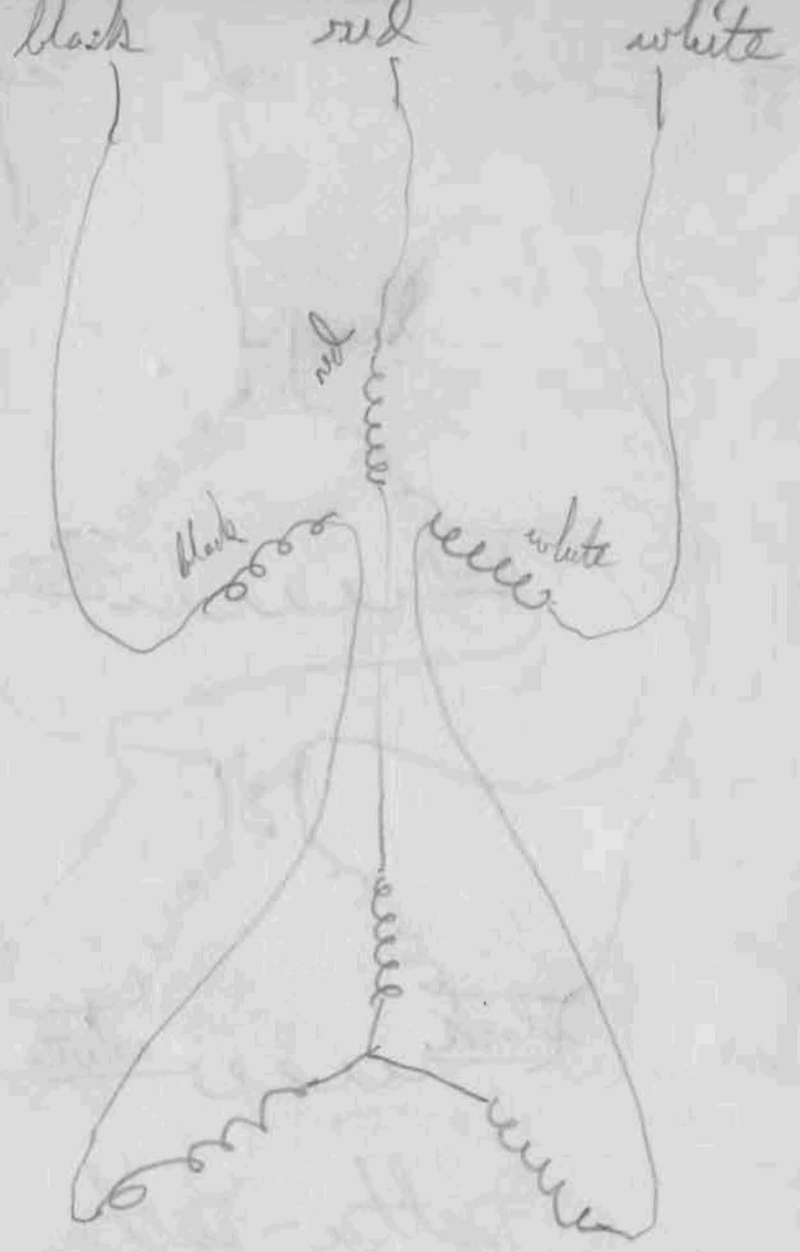
Since motors will start at 70 volts it seems best to rewire motors in two sets of series parallel arrangement, Starting current should then be about 6 amps.

April 8, 1952

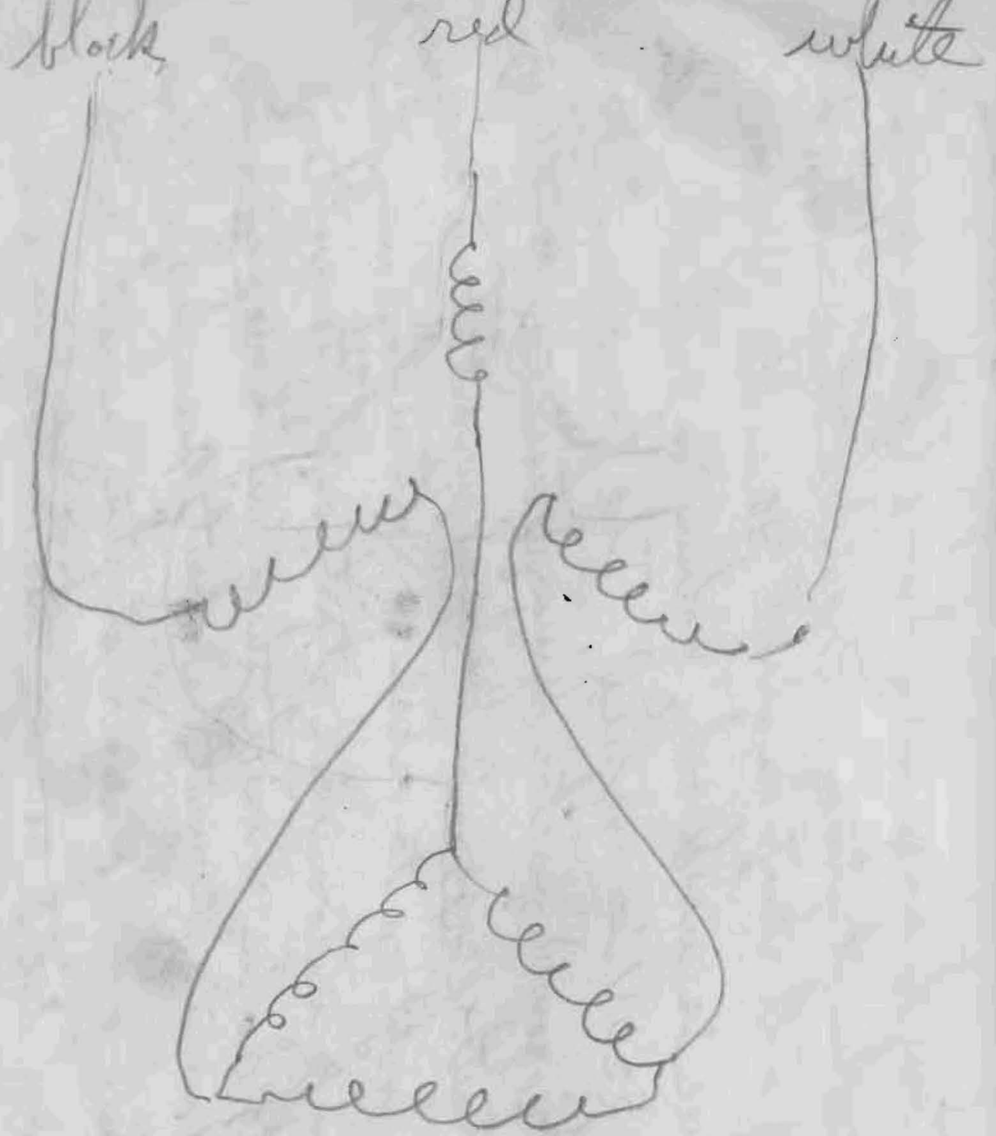
The four motors draw a very large (15 amp approx.) reactive current when starting. Provided this current is supplied they will start on about 80 volts. Where a series resistance is used only 6 ohms in each leg can be tolerated if 220V is applied. The large reactive current of lagging power factor demagnetises the field of alternator and output drops. A leading current from condensers alone will cause voltage to rise as alternator magnetization is increased. Since motors will start on little voltage the best thing to do is connect them in two pairs in series. Present running current is about 4 amperes. Thus series connection will provide lower starting current with adequate running speed as once the motors are going only 100V is necessary to operate.



Delta - Delta
series connection

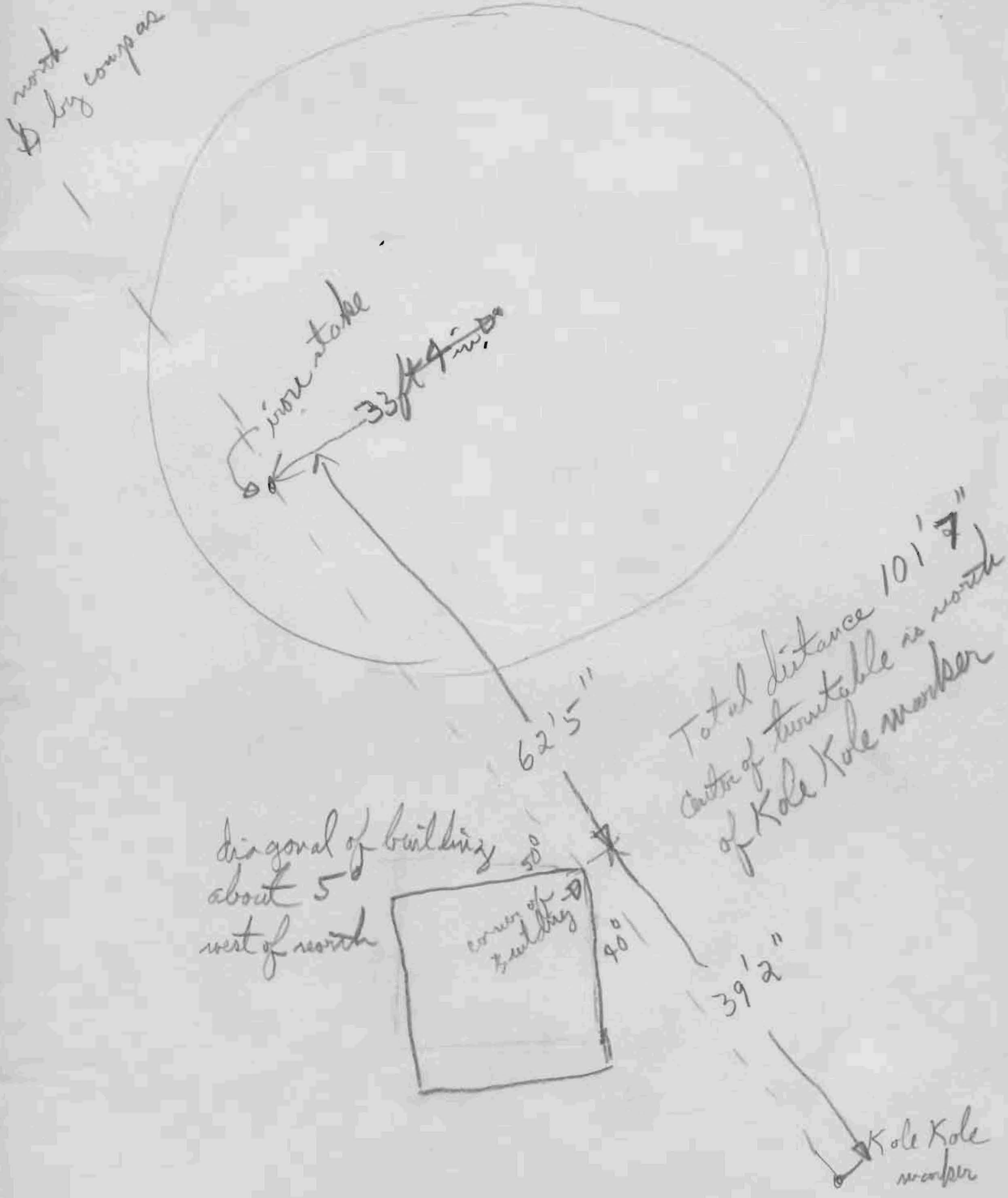


Y-Y series connection



Y-delta series connection

4-26-52



north by compass
iron stake
33ft 4in.
62'5"
Total distance 101'7"
center of turntable is north of Kole Kole marker
diagonal of building about 5° west of north
50'
corner of building
40'
39'2"
Kole Kole marker