



Rewinding 3 Phase Motor



by Niko_96

Hello everyone, i am Niko and, in this instructables i will show you, how to rewind and renew old three phase electric motor.

If you are searching for **rewinding of one phase motor** you can find it [here](#).

In this insctructables, i am going to make step forward. In next steps I will show you how to analyse motors winding, disassemble motor, remove

bearings, calculate new winding, rewind motor, reassemble it with new bearings and test motor. Rewinding is very long process. It took about two days to rewind it, replace all old parts and reassemble it.

If you have any questions you can easily message me.



Step 1: Analyse Motor

I got this motor at my university.

Three phase asynchronous motor is most common used motor in the world. It has very good efficiency and low manufacture and maintain costs. Two main parts of motor are rotor and stator. Rotor is usually made as squirrel-cage, and it is inserted in stators

flow of electric current. Current in magnetic field generates force.

Because magnetic field must rotate faster than rotor to induce voltage in rotor. That's why motor speed is a little bit less than magnetic field speed ((3000 rpm

hole. Stator is made out of iron core and winding.

Stator is used to generate magnetic field. 3 phases generates rotation magnetic field so we don't need capacitor on three phase motor. Rotation magnetic field "cut" squirrel-cage, where it induces voltage. Because cage is short-circuited, voltage generates

[Magnetic field] -- 2810 rpm [Electric motor])). That's why we call them Three phase **ASYNCHRONOUS** electric motor.



Step 2: Analyse Motor

Motors Inscription board

On the motors inscription board we can find most useful information about motor:

- Motors nominal voltage (for star (**Y**) and triangle (**D**) motor connection) [V]
- Motors nominal current (for star (**Y**) and triangle (**D**) motor connection) [A]
- Power of the electric motor [W]
- Power factor $\cos \phi$
- Rotation speed [rpm]
- Nominal frequency [Hz]



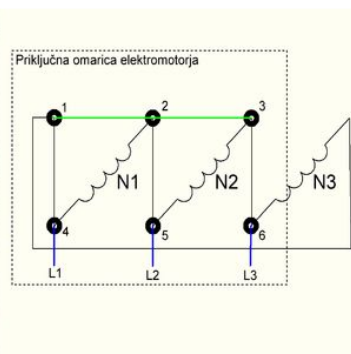
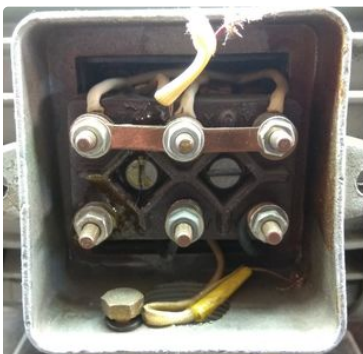
Step 3: Analyse Winding

Open the cover of conduit box.

Before measuring remove all connections in conduction box. Measure resistance for each winding, resistance between two different winding and resistance between winding and motors frame.

Resistances of three winding should be same (+/- 5%). Resistance between two winding and winding - frame should be more than 1,5 Mohm.

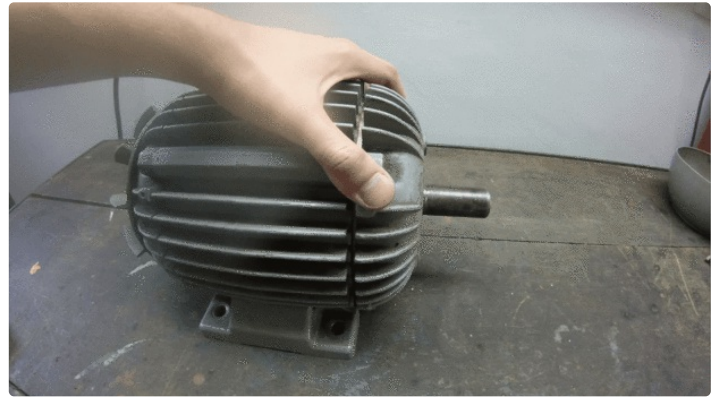
You can detect burned motors winding by unique smell (smells like burned lacquer).



Step 4: Disassembling Motor

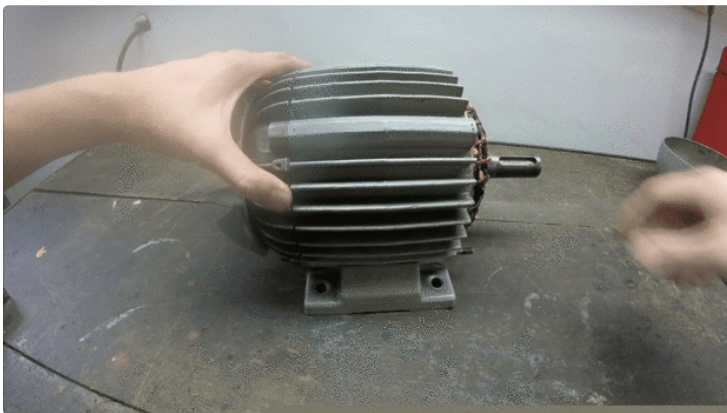
Take few picture of motor. Mark spots between first cover and stator and second cower and stator (we will need this marked points at motors assemble).

Remove covers from motor. Usually they are attached on stator by long screws. If you cant separate cover and stator you can use rubber hammer. Gently hit cover and try to rotate it. If that wont works, heat it.



Step 5: Disassembling Motor

Remove rotor from stator. You can gently hit rotors axis with rubber hammer.



Step 6: Disassembling Motor

Remove ventilator from rotors axis. I had metal ventilator so i heated it up. I separated it very easily from axis.

Remove clamp, and safety ring if you have one. Then remove second cover.



Step 7: Removal of Bearings

Use puller to remove bearings on both sides. You must be careful because you can easily damage the axis of rotor.



Step 8: Removal of Old Winding

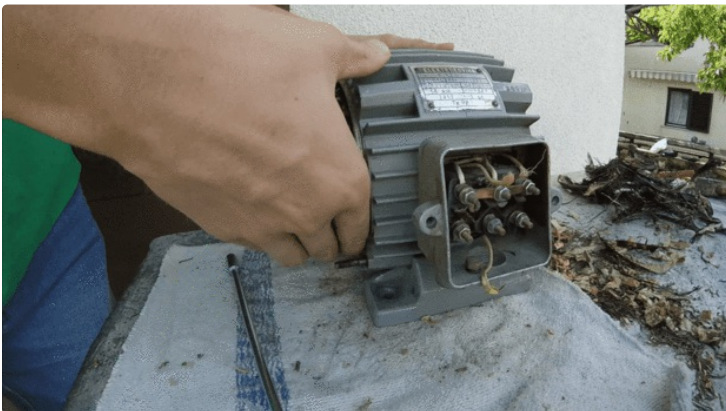
First you need to cut old winding from stator. For this job use hammer and chisels. Try not to damage stators lamellas.

Do same on both sides of stator.



Step 9: Removal of Old Winding

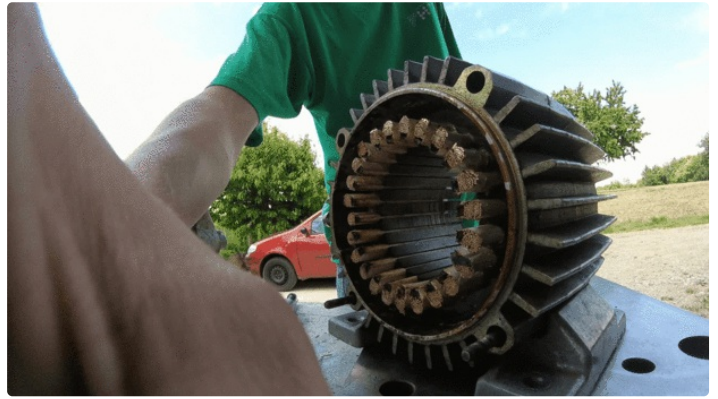
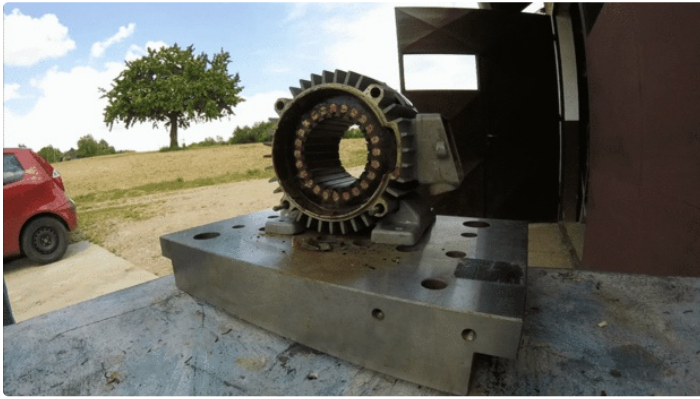
Remove connections and conduit box from stator. In next step you will need to heat up old coils, and conduit box must be empty.



Step 10: Removal of Old Winding

Heat up winding with flame torch to burn out the rest of lacquer.

If you burned old lacquer you should be able to push remain winding out of stators gaps.



Step 11: Sandblasting

Sandblasting is process where sand hits surface of workpiece with very high speed and slightly damage it.

You can easily remove old colour form motor with sandblasting. While sandblasting you need to be careful, that you don't damage surface too much, especially edges of covers.



Step 12: Paint Motor

The colour must withstand at least 100 degrees Celsius. Make sure you don't paint inscription board.



Step 13: Identification of Old Winding

You can find all information about type of old winding in "winding head". Winding head is part of winding where all connections are made.

By the winding head (Type of winding), number of wires in each gap and thickness of the wire you can rewind new motors winding without doing calculations in next step.

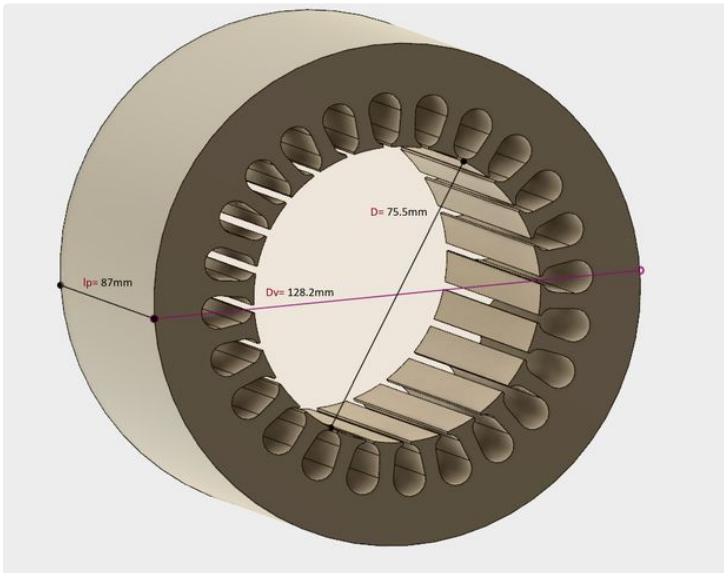


Step 14: Calculation of Parameters for New Winding

New winding of motor depends of statros package (dimensions of iron core). For better presentation i made 3D model of my statros package.

You need to measure following things:

- Length of statros package: $l_p = 87\text{mm}$;
- External diameter of statros package: $D_v = 128\text{mm}$;
- Inner diameter of statros package: $D = 75.5\text{mm}$;
- Number of statros gaps: $Z = 24$;



Step 15: Calculation of Parameters for New Winding

Now measure dimensions of statros slot.

- Width of statros slot: $b_1 = 6.621\text{mm}$; $b_2 = 8,5\text{mm}$;
- Height of statros slot: $h_u = 13.267\text{mm}$;
- Opening of statros slot: $b_0 = 2\text{mm}$;
- Height of slots "neck": $a_1 = 0.641\text{mm}$;
- Tooth width: $b_z = 3.981\text{mm}$;

I copied this picture from book [Neven Srb; Elektromotori].

Step 17: Calculate Number of Pole Pairs

Number of pole pairs depends on nominal frequencies and rotation speed of magnetic field. You can get rotation speed of magnetic field by rounding motors speed (2810) to closest value (3000, 1500, 1000, 750...).

$$p = \frac{60 \cdot f}{n_s} = \frac{60 \cdot 50}{3000} = 1$$

Where is:

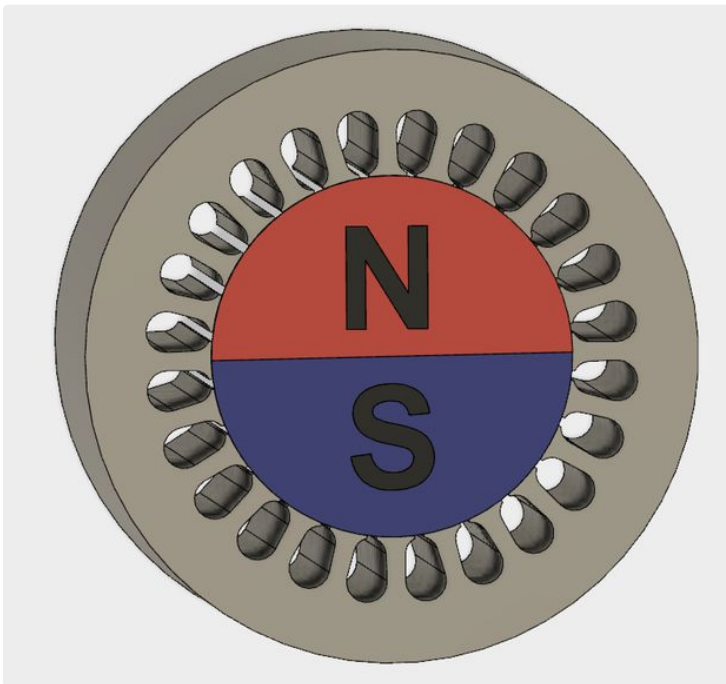
p – Number of pole pairs

f – Nominal frequency (Hz)

n_s – Rotation speed of magnetic field (°/min)

Step 18: Calculate Number of Pole Pairs

I calculated that my motor has 2 pole pairs and it generates magnetic field as you can see on upper picture.



Step 19: Calculate Pole Stepp

Pole step is distance on inner circle of stator, and it marks size of each pole.

$$\tau = \frac{\pi \cdot D}{2 \cdot p} = \frac{3.14 \cdot 75.5}{2 \cdot 1} = 118.53 \text{ mm}$$

Where is:

τ – Pole step

D – Inner diameter of stators package (mm)

p – Number of pole pairs

Step 20: Calculate Pole Surface

Pole surface is marked red on picture two. One pole surface is exactly half surface of stator, that is because i have 2 pole motor.

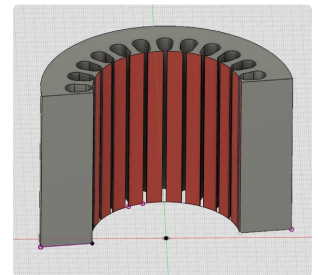
$$Q_p = \tau \cdot l_p = 118.53 \cdot 87 = 10312.11 \text{ mm}^2 = 103.12 \text{ cm}^2$$

Where is:

Q_p – Surface of pole (cm²)

τ – Pole step

l_p – Length of stators package



Step 21: Calculate Pole Surface

Because iron core of stator is not made out of pure iron we need to calculate real package length. You get iron filling factor from upper table. It depends on type of isolation.

Height of lamell in mm	Type of isolation			No isolation
	Paper	Lacquer	Phosphate	
0,50	0,88	0,90	0,92	0,94
0,65	0,90	0,92	0,94	0,96

$$l_z = k_z \cdot l_p = 0.92 \cdot 87 = 80.04 \text{ mm}$$

Where is:

l_z – Clean iron length (mm)

k_z – Iron Filling Factor

l_p – Length of the stator package

Step 22: Calculation of the Tooth Length

$$h_z = h_u + a_1 = 13.267 + 0.641 = 13.908mm$$

Where is:

h_z – Tooth length

h_u – Height of stators slot

a_1 – Height of slots “neck”

Step 23: Calculation of the Height of the Yoke of the Stator

Stators yoke is part of stators package which extends from stators tooth to end of package.

$$h_j = \frac{1}{2} \cdot (D_v - D - 2 \cdot h_z) = \frac{1}{2} \cdot (128 - 75.5 - 2 \cdot 13.908) = 12.342mm$$

Where is:

h_j – Height of the yoke

D_v – External diameter of stators package

D – Inner diameter of stators package

h_z – Tooth length

Step 24: Calculation of the Yoke Cross Section

$$Q_j = h_j \cdot l_z = 12.342 \cdot 80.04 = 987.85mm^2 = 9.88cm^2$$

Where is:

Q_j – Yoke cross section (cm²)

h_j – Yoke height

l_z – Clean iron length

Step 25: Calculation of the Cross Section of Teeth of One Pole

$$Q_z = \frac{Z \cdot b_z \cdot l_z}{2 \cdot p} = \frac{24 \cdot 3.981 \cdot 80.04}{2 \cdot 1} = 3823.671mm^2 = 38.237cm^2$$

Where is:

Q_z – One tooth cross section (cm²)

Z – Number of slots

b_z – Tooth width

l_z – Clean iron length

p – Number of pole pairs

Step 26: Calculation of the Slot Surface

$$Q_u = \frac{\pi}{8} \cdot (b_1^2 + b_2^2) + \frac{h}{2} \cdot (b_1 + b_2) = \frac{\pi}{8} \cdot ((6.621)^2 + (8.5)^2) + \frac{6.33}{2} \cdot (6.621 + 8.5) = 93.4 \text{ mm}^2$$

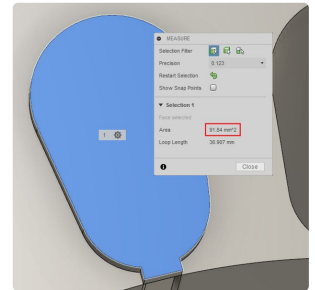
Where is:

Q_u – Slot surface (mm²)

b_1 – Slot width 1

b_2 – Slot width 2

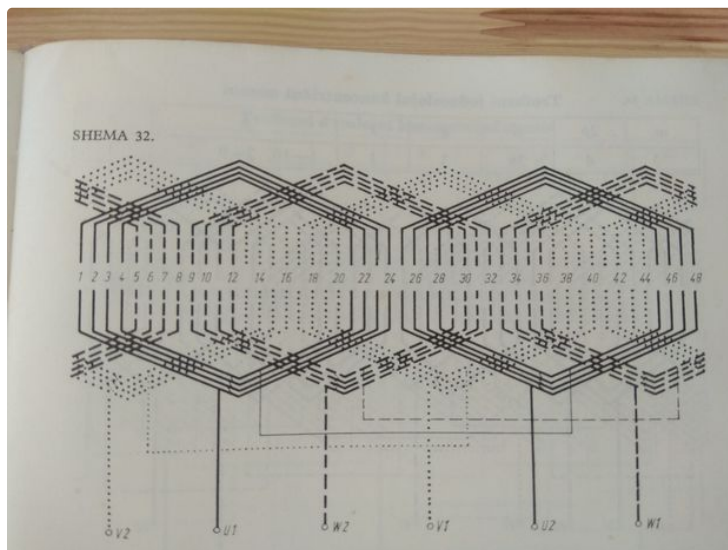
h – Distance between slot circles (watch picture of gaps in previous steps)



Step 27: Choosing the Type of Winding

I chose type of winding based on my motors specifications. In winding books there is a lot of different types of winding diagrams. Each one is drawn for different amount of pole pairs.

I took winding on the picture from winding book. My new winding was three phase single layer concentric winding.



Step 28: Calculation Number of Slots Per Pole and Phase

$$q = \frac{Z}{2 \cdot p \cdot m} = \frac{24}{2 \cdot 1 \cdot 3} = 4$$

Where is:

q – Number of slots per pole and phase

Z – Number of slots

p – Number of pole pairs

m – Number of phases in winding

Step 29: Calculation of Pole Step (in Slots)

$$\tau = \frac{Z}{2 \cdot p} = \frac{24}{2 \cdot 1} = 12$$

Where is:

τ – Pole step

Z – Number of slots

p – Number of pole pairs

Step 30: Winding Factor

There is a table in upper picture. You cant pick up winding factor from table if you have one layer winding.

q	1	2	3	4	5	6	7	8
ξ_z	1	0.966	0.960	0.958	0.957	0.956	0.956	0.955

Winding factor:

$$\xi = \xi_z + \xi_t$$

Where is:

ξ – Winding factor

ξ_z – Lane winding factor

ξ_t – Tetive winding factor

Step 31: Induction in the Air Gap

Select appropriate value of induction in air gap from table. It depends on number of pole pairs. If motor is older chose column I, else chose value from column II.

2p	B _{zr} (T)	
	I	II
2	0,6...0,7	0,75...0,85
4	0,65...0,75	0,8...0,9
6	0,65...0,75	0,8...0,9
8	0,7...0,8	0,8...0,9
10	0,7...0,8	0,8...0,9

Step 32: Calculation of the Induction in the Teeth of the Stator

$$B_z = B_{zr} \cdot \frac{Q_p}{Q_z} = 0.65 \cdot \frac{103.12}{38.237} = 1.753T$$

Where is:

B_z – Induction in teeth of stator

B_{zr} – Induction in air gap

Q_p – Surface of pole

Q_z – Cross section of the tooth

Step 33: Calculation of the Induction in the Stator Yoke

$$B_j = \frac{B_{zr} \cdot Q_p}{\pi \cdot Q_j} = \frac{0.65 \cdot 103.12}{\pi \cdot 9.88} = 2.15T$$

Where is:

B_j – Induction in stator yoke

B_{zr} – Induction in air gap

Q_p – Surface of pole

Q_j – Cross section of the yoke

2p	B _j	B _z
2	1,6...2,1	1,0...1,6
4	1,5...2,0	1,2...1,7
6	1,5...1,9	1,3...1,7
8	1,5...1,9	1,3...1,7
10	1,5...1,9	1,3...1,7

Step 34: Calculation of the Magnetic Flux of One Pair of Poles

$$\phi = \frac{B_{zr} \cdot Q_p \cdot 10^{-4}}{1.57} = \frac{0.65 \cdot 103.12 \cdot 10^{-4}}{1.57} = 0.00427 \text{ Wb}$$

Where is:

ϕ – Magnetic flux of one pole pair(Wb)

B_{zr} – Induction in air gap (T)

Q_p – Pole surface (cm²)

Step 35: Calculation of the Calculation Number of Turns in the Phase

$$w' = \frac{0.22 \cdot U_f \cdot a}{\phi \cdot f \cdot \xi} = \frac{0.22 \cdot 230 \cdot 1}{0.00427 \cdot 50 \cdot 0.958} = 247.39 \approx 247$$

Where is:

w' – Calculation number of turns in coil

U_f – Phase voltage (V)

a – Number of parallel branches

ϕ – Magnetic flux of 1 pole pair (Wb)

f – Nominal frequency (Hz)

ξ – Winding factor

Step 36: Calculation of Calculation Number of Turns in Slot

$$S'_u = \frac{6 \cdot w'}{Z} = \frac{6 \cdot 247}{24} = 61.75 \approx 62$$

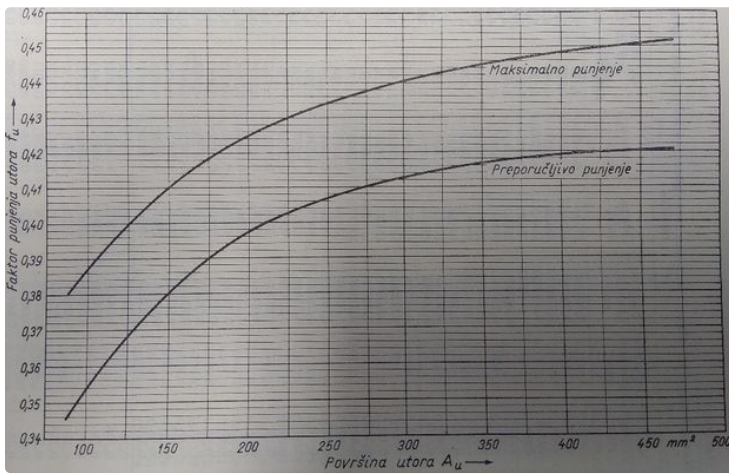
Where is:

S'_u – Calculation number of turns in slot

w' – Calculation number of turns in pole and phase

Step 37: Determine the Filling Factor

To get right filling factor you need to have surface of your slot. Then you easily write down filling factor from upper graph. Filling factor must be between upper and bottom recommended line.



Step 38: Calculation of Cross Section of the Wire

$$q'_v = \frac{Q_u \cdot f_u}{S_u} = \frac{93.4 \cdot 0.34}{62} = 0.512 \text{ mm}^2$$

Where is:

q'_v – Cross section of the wire

Q_u – Surface of slot

f_u – Filling factor

S_u – Number of turns in gap

Step 39: Calculation of Thickness of Wire

According to the result you pick a wire which is in +/-2% range of result. I picked 0,8mm wire.

$$d'_z = 2 \cdot \sqrt{\frac{q'_v}{\pi}} = 2 \cdot \sqrt{\frac{0.512}{3.14}} = 0.807$$

Where is:

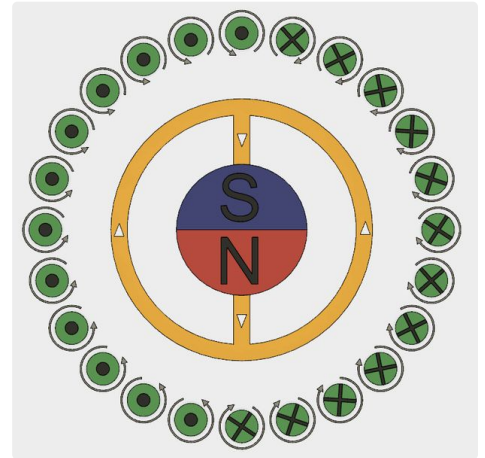
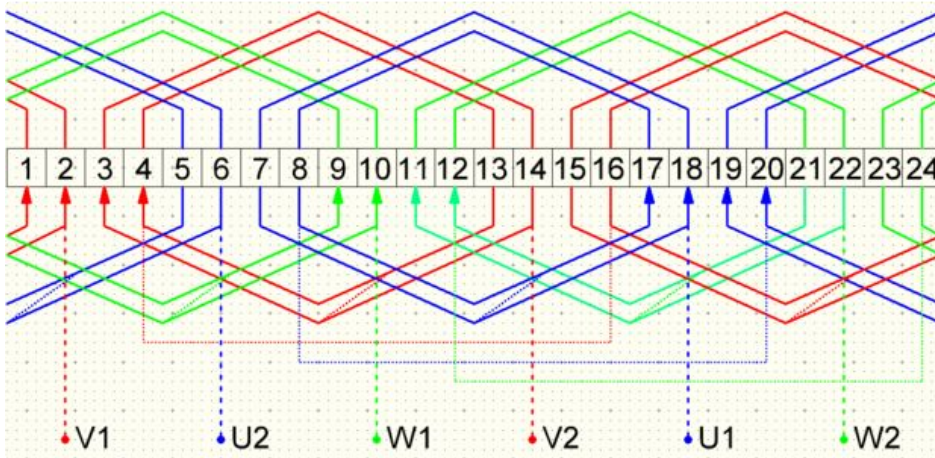
q'_v – Cross section of the wire (mm)

d'_z – Thickness of wire (mm)

Step 40: Winding Diagram

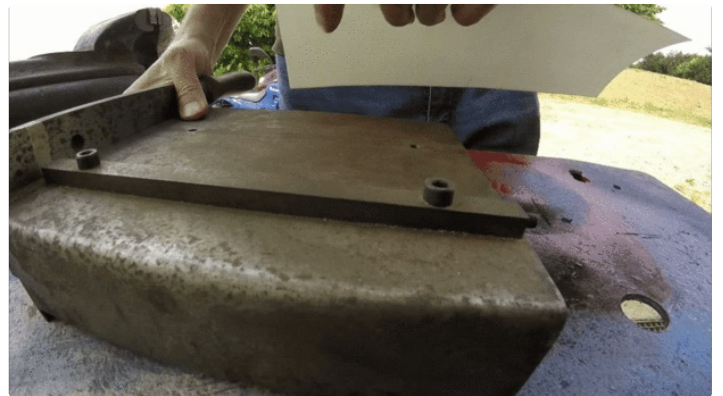
I remade winding diagram from book, so it fits into my stator. I draw new winding diagram which i had used at winding motor.

Second picture is showing the magnetic field generated by stators winding. O and X are showing direction of electric current. Current which is flows inside picture has clockwise direction of magnetic field. If would had 4 pole motor we would have 4 areas instead of 2 areas of magnetic field.



Step 41: Isolating Stators Slots

Measure length of slot, and add about 16mm (depends of how you will twist paper). Cut it and twist it as I have done on gifs. Put isolate paper on table, and place ruler on it, so you get about 4mm gap in witch you will insert isolate paper and then twist it. Use screwdriver to bend it and insert it in gap. It should fit perfectly so you cant pull it out.





Step 42: Measure Length of Coils

Make model of coil. Place model in right slots, leaving some free space. You must not leave too much space, because winding would be too bit, and you must not make it too small, because you will not be able access to all slots.



Step 43: Winding Coils

Place model in special tool. Free 3d model of winding tools are available on "Rewinding one phase motor" instructables. Make sure you wind correct number of turns. After you wind coil you need to tie it up with piece of wire. Then you can take it of winding tool.



Step 44: Inserting Coils in Stators Slots

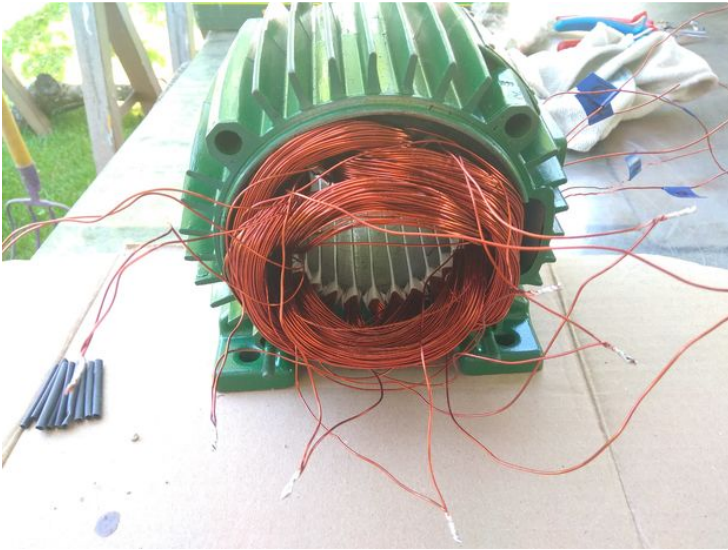
Careful place coils in stators slots. This can take a long time to do. Be gently so you don't damage wires lacquer. Rotate coils so their end wires will come out on the side, where is the hole from stator to electrical clips. You can use wooden stick to put winding in slots.

Mark ends of coils!



Step 45: Connecting Coils

Wire coils together according to winding diagram. Solder and isolate them. End of each coil wire to conduit box and extra isolate them.



Step 46: Bind the Coils

Bind the coils with the stator lacing thread. Sew stator lacing thread around coils, as you can see on pictures. Tight winding well.



Step 47: Varnishing the Motor

1. Heat up cooking oven to 100 °C. Put motor in it.
2. When motor heats up, spills lacquer on motors coils as you see on pictures
3. Turn motor around and do the same
4. You can reuse old lacquer.
5. Put motor in hot oven, and cook it for about 4 hours
6. Take motor out and clean edge (so cover will fit perfectly).

DON'T DO IT INSIDE BUILDING OR KITCHEN!



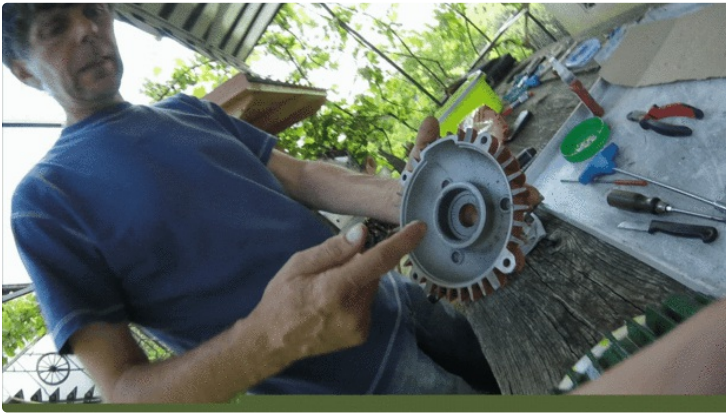
Step 48: Reassemble Motor

Attach new bearings. Lubricate axis of rotor. You find type of bearing on side of bearing. If you cant find it, you can measure it and find number in catalogue on internet.



Step 49: Reassemble Motor

Attach cover on stator. Watch marks to put it into right place.



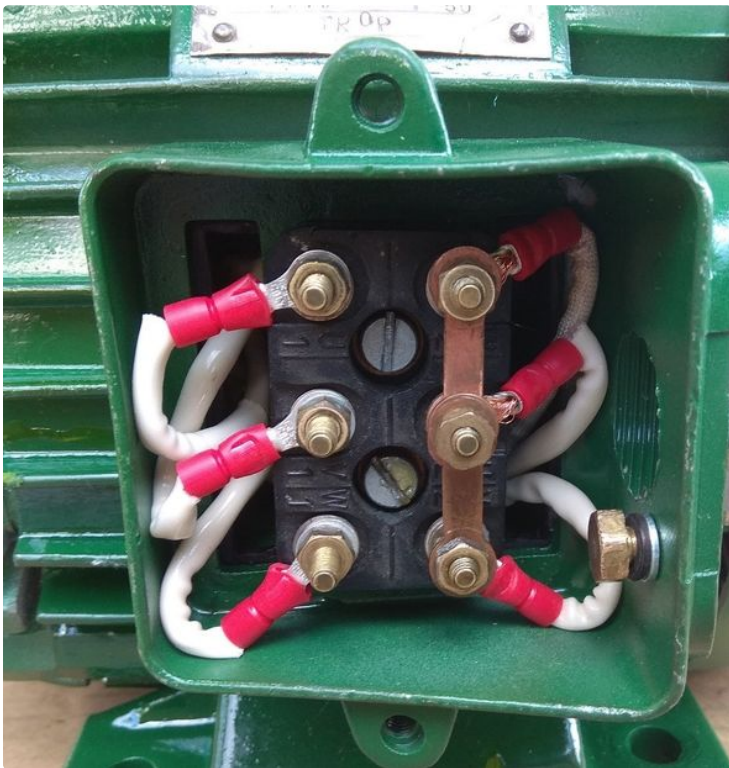
Step 50: Reassemble Motor

Put rotor in stator, and close it with second cover. Screw motor together.



Step 51: Reassemble Motor

Connect end of coils to clips, according to picture from analyse motor.



Step 52: Reassemble Motor

Put ventilator and last cover on motor. If you have iron ventilator heat it.

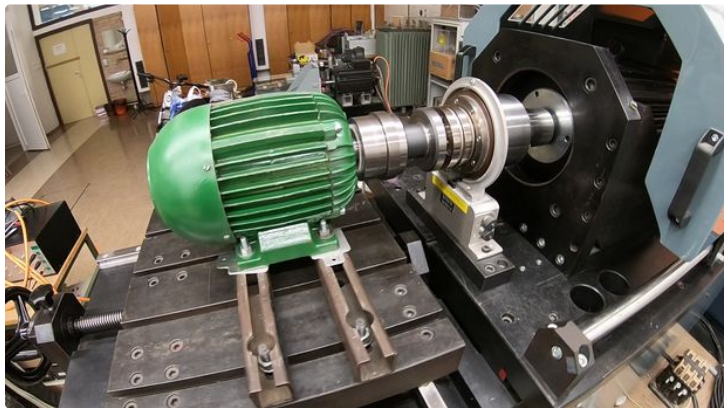


Step 53: Measurement

I took refurbished motor to university to make measurements. We mounted motor on special test device, and connected it with measurement equipment. We tested next things:

- Resistance of winding
- Free running test of an electric motor
- Test of the loaded electric motor
- Optimal voltage test
- Short circuit test
- Torque characteristic

*PF = Power factor



Measurement of resistance

Winding	resistance [Ω]
R ₁	4,5
R ₂	4,66
R ₃	4,18
R ₁₃	8,68
R ₁₂	9,16
R ₂₃	8,84

Free run motor test

U [V]	I [A]	P _{in} [W]	PF	P _{cu} [W]	P _{fe} [W]	P _{fw} [W]
380,0	1,18	160	0,206	18,9	34,2	106,9
400,0	1,33	1,68	0,183	23,9	37,7	106,9

Loaded motor test

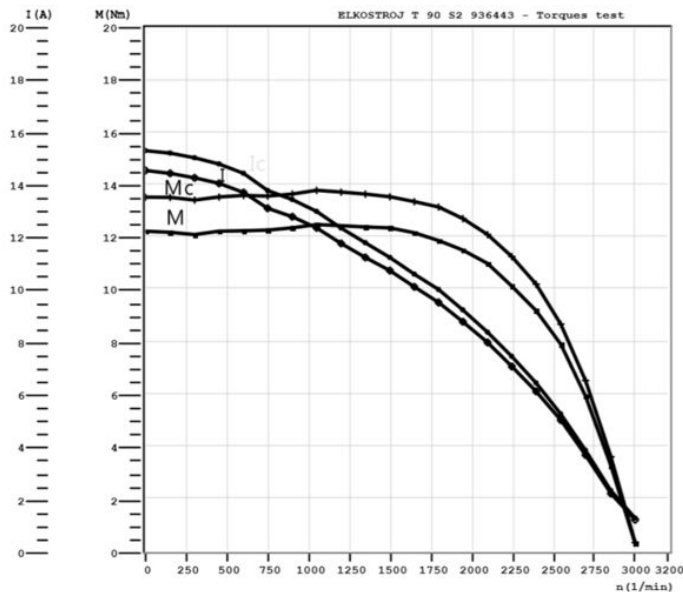
U (V)	I (A)	P _{in} (W)	PF	M (Nm)	n (1/min)	P (W)	EFF	P _{loss} (W)
379,9	3,31	1996	0,903	5,3	2700,9	1500	0,763	465,7
399,9	3,1	1892	0,88	5,18	2763,5	1500	0,793	392,1

Optimal voltage test

U (V)	I (A)	P _{in} (W)	PF	M (Nm)	n (1/min)	P (W)	EFF	P _{loss} (W)
440,3	2,99	1853	0,812	5,05	2833,1	1499,7	0,809	353,7

Short circuit test

U (V)	I (A)	P _{in} (W)	PF	M (Nm)
94,7	3,28	362	0,673	0,6



Torque characteristic

Step 54: Conclusion

It took me about a week to rewind this motor. Most time i spent on calculation of new winding. I had a lot of problems with calculation but i solved them and i got same parameters of winding as were on old one.

I had a lot of problems with winding new winding too. First i made coils too small, and i couldn't insert last coils in slots. I couldn't access to them because other winding were too small. Then i decide to make bigger one but i found problem again. This time winding was too big and i couldn't close the cover of motor.

Third time i successful rewind motor. Because gap between stator and cover was very small, i decided to do a little bit bigger first coils, and a little bit smaller last coils. You can se that on measurment of resistance where, winding resistances aren't identical. But in next measurement we can see that resistances do not dramatically affect on electric motors performance.

I made all tests with two different voltages. Motor was made for voltage 380V, but now we have 400V in EU.

In upper table there is data from manufacturer in first line. In second line is measurement at 380V and third line at 400V. If we compare all data we can see that motor isn't bad at all. All parameters are very close together.

I took all electrical equations and orientation tables from book: Neven Srb ELEKTROMOTORI

I hope you enjoined my presentation of rewinding a three phase motor. If you have any questions please ask, and i will try to answer ass soon as possible. Thank you for your attention.

Best regards Niko



Comparison

U (V)	I (A)	P (W)	PF	n (1/min)	f (Hz)
380	3,35	1500	0,87	2810	50
380	3,31	1500	0,903	2700	50
400	3,1	1500	0,88	2763	50



Lol - too much maths. why did you not just wind the thing



I want to show you that you can calculate parameters for winding only with dimensions of stators packet.



yeah i know. just a huge read. ;-) nice work.



Well Done. I am impressed.

That may mean more from me than most because I was a Work Center Supervisor of a Motor Rewind shop in the US Navy. Served on CV-61 and CVS-67 which dates me. To RobB162 In general, I concur. However, while underway and a main fire pump dies, you can't just grab one from the store. (And some of our equipment was "One of a Kind" too)

We had the following in our shop that helped:

1. Burn Oven - Walk-in oven that you placed Stator in to burn the old varnish
2. Filing Cabinet(grin) - Held documentation on every motor that passed thru the shop. Only had to do the calculations once. From then on, they were referenceable :)
3. Rewind Head - Dial in the correct size & number of turns, Feed 1 end of wire in, and let it go. When done, you can tie the wire bundles before you remove them. Perfectly wound, every time
4. Dip Tank - Tank of Varnish, large enough to submerge the finished stator. (Was a pain in the *** to keep the viscosity of the varnish correct.)
5. Overhead Trolley - to move the motor parts around (The ones we worked on could weigh in over a Ton)
6. Bake Oven - When all done, nothing like a nice long bake to "Set" the varnish.
7. Lots of E2-E5 (Nothing like lots of helping hands)

But beyond those surface differences, we did things **exactly** the same. And yes, the hardest part was actually inserting the new coils without damaging them.[Wooden Push Sticks are a MUST!]

- I have toured the different shops on ships and always admired the ability to repair or make what was needed underway. The Ranger must have one heck of a place
- Superb congratulations. I realize now how much work this is.
- Very good work... Well Done and Keep it up



Awesome, thanks for the detail!

- awesome work
- Wow; Bravo; very well done! Thanks for such an invaluable contribution; one never really knows what the future may hold.

Is that a mango tree in the background?



Thx, and it is cherry tree :D.



Working as an industrial electrician this is counter productive vs purchasing a new one. However, some fantastic learning to be gained from this. I plan on having our apprentice look through this and also work through the calculations. Fantastic detail. Thanks for the time commitment and also for a great instructable!



I was curious about what the economics were for rebuilding such motors... Could somebody make a living rebuilding these?



Typically we will only rewind over 10hp. We will do bearings and seals on any size motor but when rewinding is upwards of 70%+ of new when rewinding below 10hp, it just doesn't make sense. But yes there are companies out there that specialise in motor testing and rewinding.



That makes a lot of sense. Thanks for your reply, I love learning about these things.



Niko_96

Thank You. Very Interesting and informative.

Philsky49



Fascinating read, thank you. In college, one of the hardest classes I took was on multi-phase and power transmission. This inspires me to dig out my old textbooks and brush up.

◦ Excellent



This is a fantastic Instructable...and the parts I find most valuable are the explanations of what you did wrong, your problems, and the solutions...THANK YOU!

◦ Congratulations ! You did a very didactic class!

◦ Very nice write up. I was just in a commercial motor build rebuild shop a month ago, and I have to be honest, your explanation was just as good, if not better, than that which I got from the motor house. This is coming from an electrical engineer. I am truly impressed, as this is probably one of the most difficult tasks someone could ever take on!

◦ Very impressive!! Thanks a lot!

◦ A Double WOW!!!! I am so impressed by the level of skill, detail & information your project shows. #1) I have a better understanding of motors after watching you deconstruct several. #2) I have a renewed appreciation for the 20+ motors that make my home comfortable. Thanks for all the work!!!!



Wow ...I was going to try to rewind a 30KW generator but I'm rethinking that right now