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10-pole PM-generator

In November 2016 I have visited a local company in Dar es Salaam, Tanzania for a PUM-mission. They have shown me the armature of a 10-pole PM-generator or a 10-pole PM-motor which was saved from a scrap yard. The stator with the windings wasn't available. The armature had ten rows of PM-magnets which were curved at the outside. At that time I could not understand why one has made a 10-pole armature as this requires a stator with 30 slots for a normal winding and stators with 30 slots are not standard available. But after thinking about it, I now may have found the explanation for this choice of ten armature poles.

If the stator has 36 slots, and so 36 stator poles, the optimum choice for the number of armature poles is 12 because then you get a simple 2-layers winding. However, this means that every magnet is opposed to a stator pole and this causes a strong preference position. If the armature has rotated 10°, you have the same situation. So there are 36 strong preference positions per revolution. This is very unfavourable if the generator is used for a wind turbine because it results in a high starting wind speed. Another disadvantage is that the generator will be rather noisy as these preference positions will cause a strong vibration.

If the stator has 36 slots, and so 36 stator poles and if the armature has ten poles, only two of that ten poles will be opposite to two stator poles at a certain moment. For four armature poles the angle will be 2° and for four armature poles the angle will be 4°. So if the armature has rotated 2°, two other armature poles are opposed to two other stator poles. This means that the armature will have 180 preference positions per revolution and the peak torque for each preference position will be much less strong than for a PM-generator with 12 armature poles. So this must be the reason why one has chosen for 10 armature poles in combination with a stator with 36 stator poles.

However, an armature with 10 poles and a stator with 36 slots gives problems with the winding. The armature pole angle for an armature with ten poles is 360 / 10 = 36°. So the ideal stator coil pitch would be 36° too. But this isn't possible as the pitch in between two adjacent stator slots is 10°. Another problem is that each phase can have five single coils, so the total stator winding has 15 coils and these coils make use of 30 slots. But this means that six slots are not used. If the six non used slots are lying at an angle of 60° with respect to each other, it is possible to lie a 3-phase winding. Every phase has three coils with a coil pitch of 40° and two coils with a coil pitch of 30°, so the average coil pitch is 36°. However, I don't like it that six slots are empty because this reduces the maximum power which can be generated at a certain rotational speed.

This problem can be solved by using one set of double coils and four single coils in each phase. A set of double coils has an inner coil with a coil pitch of 30° and an outer coil with a coil pitch of 50°. Two single coils have a coil pitch of 30° and two single coils have a coil pitch of 40°. The sets of double coils must be positioned such with respect to each other that the angle in between the sets is 120°. Figure 1 shows the coils for this configuration.

For the armature which was shown to me, magnets were used for the north and for the south poles. This has as disadvantage that a lot of magnetic material is used and that the magnets will scratch along the stator poles when the armature is mounted in the stator. As the magnets are rather thick, I think that it is possible to use only magnets for the north poles and to use the remaining material of the armature for the south poles.

The magnets of the shown armature were rounded at the outside. This has as effect that the gap is minimal at the heart of the magnet but that it is much larger at the sides. This may have a favourable influence on the peak of the sticking torque. If flat magnets are used, the gap is maximal at the heart and minimal at the sides. A disadvantage of rounded magnets is also that there is almost no choice for standard magnets and they will therefore be more expensive per volume. So in figure 1 I have used flat magnets for the north poles and no magnets for the south poles. I have used a stator stamping of Kienle & Spiess for a 6-pole 0.55 kW motor frame size 80 (see www.kienle-spiess.de). This motor has a stator stamping with an outside diameter of 120 mm, an inside diameter of 80 mm and a stator length of 90 mm. Assume the air gap in between armature and stator is 0.3 mm, so the armature diameter is 79.4 mm. Assume three neodymium magnet size 30 * 20 * 10 mm are used in an armature groove. So totally fifteen magnets are needed. These magnets are supplied by the Polish company Enes, website: www.enesmagnets.pl. The price including VAT, excluding postage, is € 2.67 per magnet if 30 magnets are ordered. So the total magnet price is about € 40 which seems reasonable. I don't know if 180 preference positions is large enough to guarantee a sufficient low starting wind speed for a windmill rotor with a certain geometry.

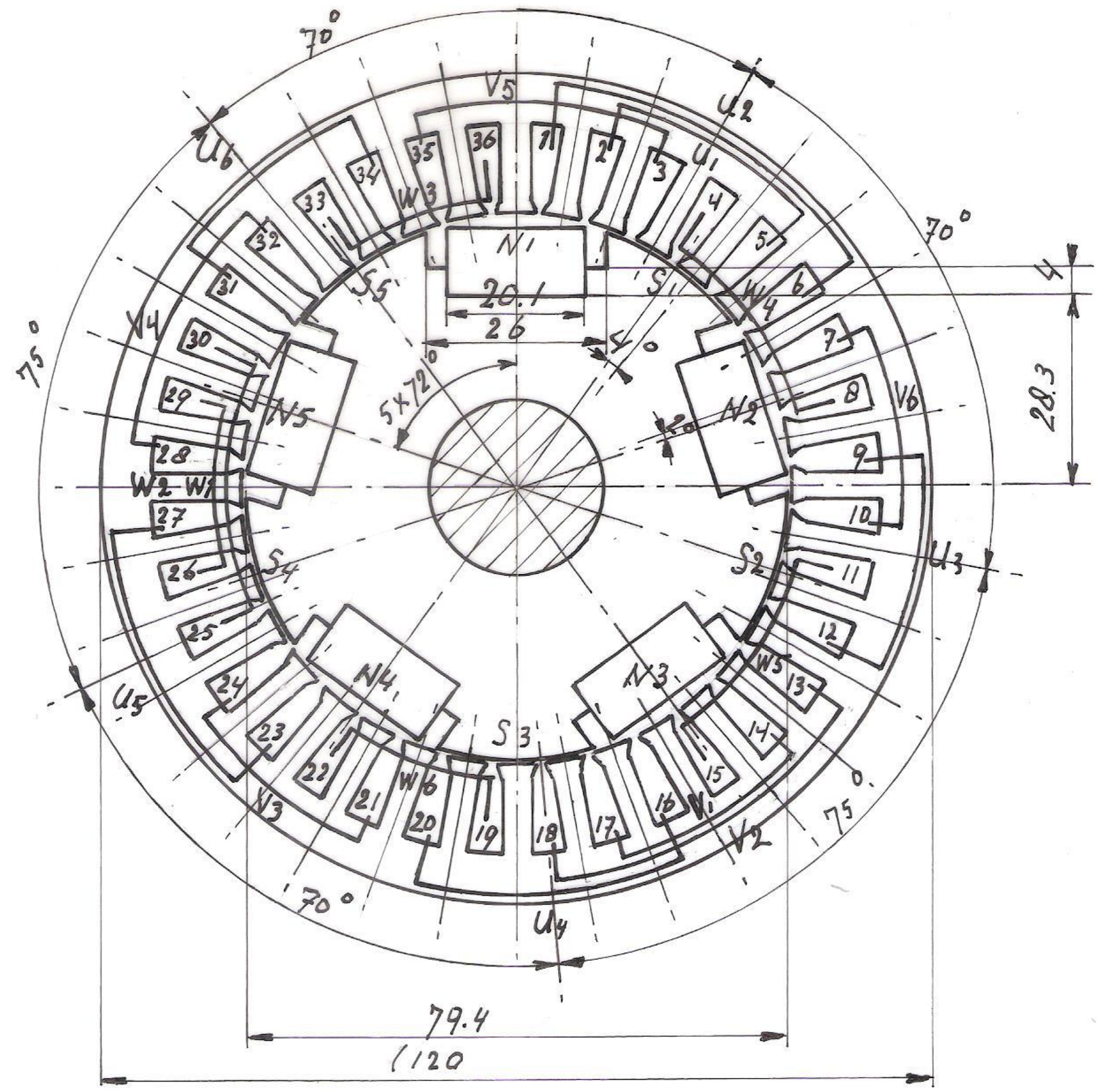

fig. 1 10-pole PM-generator using stator stamping of a 6-pole motor frame size 80