CLAIMS

1. An intravascular blood pump for insertion into a patient's body, the pump comprising:

an elongate housing having a proximal end connected to a catheter and a distal end connected to the pump, the housing having a longitudinal axis; and

a slotless permanent magnet motor contained within the housing, the motor having p magnet pole pairs and n phases, where p is an integer greater than one, and n is an integer ≥3, the motor comprising:

a stator winding having 2np coils wound to form two coils per phase per magnet pole pair such that a coil from each phase is circumferentially arranged next to a coil from a different phase in a sequential order of phase, the arrangement repeated along the stator winding such that each coil of the 2np coils spans 360/(2np) mechanical degrees about a cross section of the stator winding each coil having an inner layer and an outer layer, the outer layer overlaid on the inner layer, and

a permanent magnet rotor supported for rotation and configured to generate a magnetic flux for interaction with the stator winding,

wherein the two coils per phase per magnet pole pair of the stator winding are connected in series such that a direction of current flow through a first coil of the two coils is opposite to a direction of current flow in a second coil of the two coils, the current flow in the first coil and the current flow in the second coil interacting with opposite polarities of the magnetic flux of the rotor for producing torque in the same direction, thereby facilitating rotation of the rotor for a flow of blood through the pump.

2. The intravascular blood pump of claim 1, wherein each of the coils comprise either N/2 winding turns or (N±1)/2 winding turns, where N is a number of winding turns in a coil of a conventional stator winding having np coils wound to form one coil per phase per magnet pole pair, where N is an integer ≥1.

3. The intravascular blood pump of claim 1, wherein the two coils per phase are connected in series such that their start terminals or their end terminals are connected together.

4. The intravascular blood pump of claim 1, wherein the two coils per phase are connected to the coils of the other phases in either a star or a delta configuration.

5. The intravascular blood pump of claim 1, wherein the 2np coils comprise any one of helical windings, rhombic windings, conventional windings and hybrid windings.

6. The intravascular blood pump of claim 1, wherein the stator winding has a coil usage function that defines a vertical component of the coil relative to a longitudinal length of the stator winding that interacts with a magnetic field of the rotor to contribute to the torque generated in the motor, the coil usage function maximized when the vertical component is two-thirds the longitudinal length of the stator winding.

7. The intravascular blood pump of claim 6, the coil usage function has the same form for all phases and is shifted by 360/n electrical degrees for each phase.

8. The intravascular blood pump of claim 7, wherein the coil usage function defines a vertical component of a coil relative to the longitudinal length of the stator winding that contributes to a torque generated in the motor.

9. The intravascular blood pump of claim 1, wherein the motor comprises a three-phase two-pole machine.

10. The intravascular blood pump of claim 1, wherein the motor comprises a six-coil two-pole machine, each coil spanning 60 mechanical degrees about the cross section of the stator winding.

11. The intravascular blood pump of claim 9, wherein the motor generates a torque constant that is about 15.5% greater than the torque generated by a motor having a stator winding with np coils wound to form one coil per phase per magnet pole pair.

12. The intravascular blood pump of claim 1, wherein the rotor pumps blood at a rate between about 1.0 lpm and about 6.0 lpm.

13. A slotless permanent magnet electric motor having p magnet pole pairs and n phases, where p is an integer greater than one, and n is an integer ≥ 3, the motor having a longitudinal axis and comprising:

a stator winding having 2np coils wound to form two coils per phase per magnet pole pair such that a coil from each phase is circumferentially arranged next to a coil from a different phase in a sequential order of phase, the arrangement repeated along the stator winding such that each coil of the 2np coils spans 360/(2np) mechanical degrees about a cross section of the stator winding each coil having an inner layer and an outer layer, the outer layer overlaid on the inner layer, and

a permanent magnet rotor supported for rotation and configured to generate a magnetic flux for interaction with the stator winding,

wherein the two coils per phase per magnet pole pair of the stator winding are connected in series such that a direction of current flow through a first coil of the two coils is opposite to a direction of current flow in a second coil of the two coils, the current flow in the first coil and the current flow in the second coil interacting with opposite polarities of the magnetic flux of the rotor for producing torque in the same direction, thereby facilitating rotation of the rotor.

14. The slotless permanent magnet electric motor of claim 13, wherein each of the coils comprise either N/2 winding turns for even values or (N±1)/2 winding turns for odd values of N, where N is a number of winding turns in a coil of a conventional stator winding having np coils wound to form one coil per phase per magnet pole pair, where Nis an integer ≥1.

15. The slotless permanent magnet electric motor of claim 14, wherein the resistance of the two coils connected in series per phase is equivalent to the resistance of a single coil of a stator winding.

16. The slotless permanent magnet electric motor of claim 13, wherein the two coils per phase are connected in series such that their start terminals or their end terminals are connected together.

17. The slotless permanent magnet electric motor of claim 13, wherein the two coils per phase are connected to the coils of the other phases in either a star or a delta configuration.

18. The slotless permanent magnet electric motor of claim 13, wherein the 2np coils comprise any one of helical windings, rhombic windings, conventional windings and hybrid windings.

19. The slotless permanent magnet electric motor of claim 13, wherein the stator winding has a coil usage function that defines a vertical component of the coil relative to a longitudinal length of the stator winding that interacts with a magnetic field of the rotor to contribute to the torque generated in the motor, the coil usage function maximized when the vertical component is two-thirds the longitudinal length of the stator winding.

20. The slotless permanent magnet electric motor of claim 19, wherein the coil usage function has the same form for all phases but shifted by 360/n electrical degrees for each phase.

21. The slotless permanent magnet electric motor of claim 13, wherein a coil usage function defines a vertical component of a coil relative to the longitudinal length of the stator winding that contributes to a torque generated in the motor.

22. The slotless permanent magnet electric motor of claim 13, wherein the motor comprises a three-phase two-pole machine.

23. The slotless permanent magnet electric motor of claim 13, wherein the motor comprises a six-coil two-pole machine, each coil spanning 60 mechanical degrees about the cross section of the stator winding.

24. The slotless permanent magnet electric motor of claim 22, wherein the motor generates a torque constant that is about 15.5% greater than the torque generated by a motor having a conventional stator winding with np coils wound to form one coil per phase per magnet pole pair.