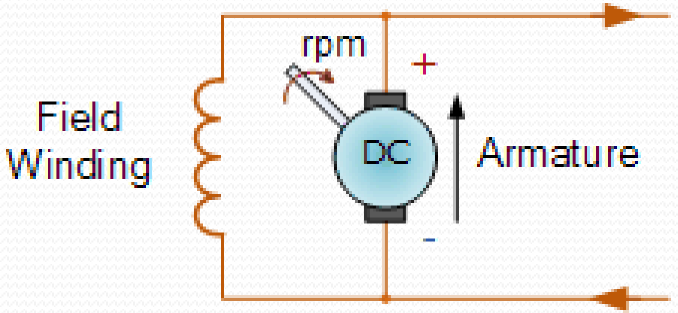
DC generators

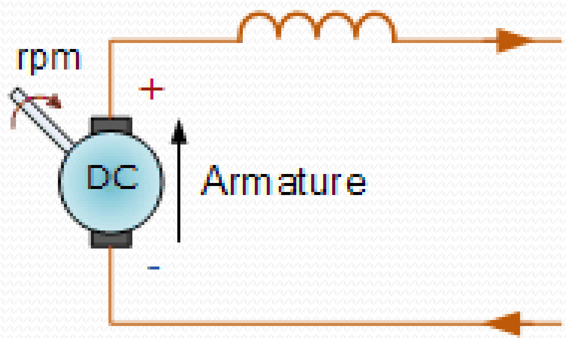
- One such electrical generator which we can use in a wind power system is the **Permanent Magnet DC Generator**.
- Direct current (DC) machines can be used as either conventional motors or as DC wind turbine generators as constructionally there is no basic difference between the two.
- In fact, the same DC machine may be driven electrically to move a mechanical load, or it may be driven mechanically to generate an output voltage.
- This then makes the *permanent magnet DC generator* ideal for use as a wind turbine generator.

- Generally with conventional DC machines, the field winding is on the stator and the armature winding is on the rotor.
- This means that they have output coils that rotate with a stationary magnetic field that produces the required magnetic flux.
- Electrical power is taken directly from the armature via carbon brushes with the magnetic field, which controls the power, being supplied by either permanent magnets or an electromagnet.
- The rotating armature coils pass through this stationary, or static magnetic field which in turn generates an electrical current in the coils.
- In a permanent magnet DC generator, the armature rotates so the full generated current must pass through a commutator or slip-rings and carbon brushes arrangement providing electrical power at its output terminals as shown.

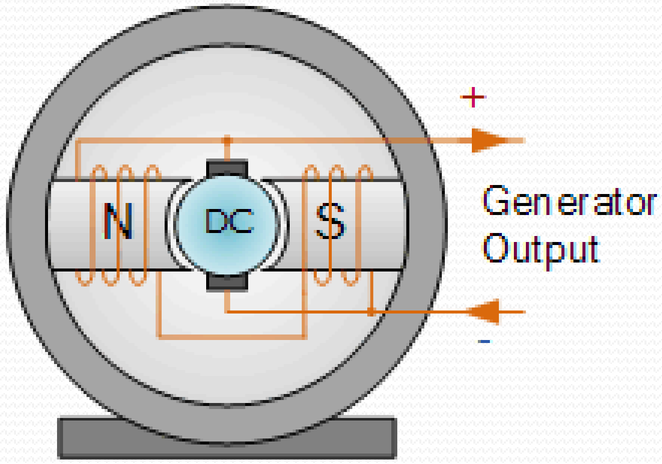
Typical DC generator constructions

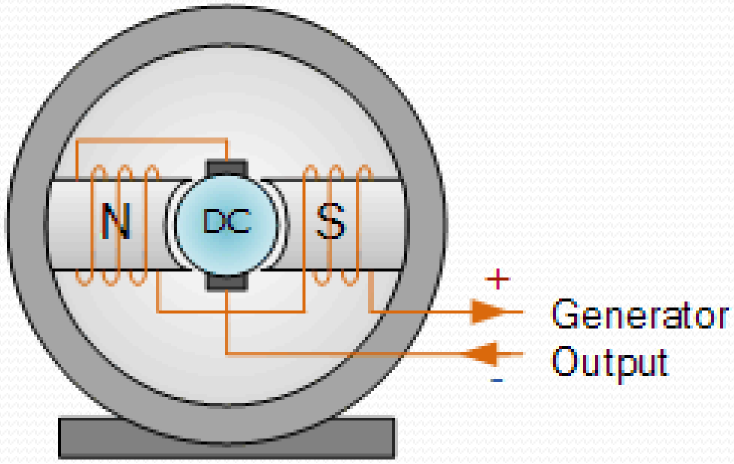


Shunt Wound DC Generator



Series Wound DC Generator





Shunt wound DC generator

- In these generators, the field (excitation) current, and hence magnetic field, increases with operating speed as it is dependant upon the output voltage.
- The armature voltage and electrical torque also increase with speed.
- The shunt-wound generator, operating at a constant speed under varying load conditions, has a much more stable voltage output than does the series-wound generator.
- However, as the load current increases the internal power loss across the armature causes the output voltage to decrease proportionally.
- As a result, the current through the field decreases, reducing the magnetic field and causing voltage to decrease even more and if load current is much higher than the design of the generator, the reduction in output voltage becomes so severe resulting in large internal armature losses and overheating of the generator.
- As a result, **shunt wound DC generators** are not normally used for large constant electrical loads.

Series wound DC generator

- The field (excitation) current in a series wound generator is the same as the current the generator delivers to the load as they are both in series.
- If the connected load is small and only draws a small amount of current, the excitation current is also small.
- Therefore, the magnetic field of the series field winding is too weak and the generated voltage is also low.
- Likewise, if the connected load draws a large current, the excitation current is also high.
- Therefore, the magnetic field of the series field winding is very strong, and the generated voltage is high.
- One main disadvantage of a series wound DC generator is that it has poor voltage regulation, and as a result, **series wound DC generators** are not normally used for fluctuating loads.

Permanent magnet DC generator

- A "permanent magnet DC generator" can be considered as a separately excited DC brushed motor with a constant magnetic flux.
- In fact, nearly all permanent magnet direct current (PMDC) brushed motors can be used as permanent magnet DC generators, but as they are not really designed to be generators, they do not make good wind turbine generators because when working as a DC generator, the rotating field acts like a brake slowing down the rotor.
- These DC machines consist of a stator having rare earth permanent magnets such as Neodymium or Samarium Cobalt to produce a very strong stator field flux instead of wound coils and a commutator connected through brushes to a wound armature as before.

- When used as permanent magnet DC generators, PMDC motors generally have to be driven a lot faster than their rated motor speed to produce anything near to their rated motor voltage so high voltage, low rpm DC machines make better DC generators.
- The main advantage over other types of DC generator is that the permanent magnet DC generator responds to changes in wind speed very quickly because their strong stator field is always there and constant.
- Permanent magnet DC generators are generally lighter than wound stator machines for a given power rating and have better efficiencies because there are no field windings and field coil losses.
- Also, as the stator is provided with a permanent magnet pole system, it is resistant to the effects of possible dirt ingress.
- However, if not fully sealed, the permanent magnets will attract ferromagnetic dust and swarf which may cause internal damage.
- The permanent magnet DC generator is a good choice for small scale wind turbine systems as they are reliable, can operate at low rotational speeds and provide good efficiency especially in light wind conditions as their cut-in point is fairly low.

- The DC voltage generated by a permanent magnet DC machine is governed by the following three factors:
  - The magnetic field developed by the stator. This depends upon the physical size of the generator and the strength and type of the permanent magnets used.
  - The number of turns or loops of wire on the armature. This value is fixed by the physical size of the generator and armature and by the size of wire conductor. The more turns used the higher the output voltage. Likewise, the larger the wire diameter or cross sectional area the higher the current.
  - The rotational speed of the armature which is governed by the speed of the rotor blades relative to the wind velocity. For PMDC motors and generators, output voltage is proportional to speed and is generally linear.

- For small scale wind turbine systems which are used to charge batteries, the most common type of permanent magnet DC generator is the **Dynamo**.
- Dynamos are a good choice for newcomers to wind power as they are large, heavy and generally have very good bearings, so you can mount fairly hefty rotor blades directly onto their pulley shaft.
- Old style diesel truck or bus dynamos are a better choice for wind turbines as they are designed to generate the required voltage and current at slower speeds with the emphasis on efficiency rather than on maximum power.
- Also, most bus and truck dynamos can generate power up to 500 watts at 24 volts which is more than enough to charge batteries and power lights for a small scale low voltage system.

- Other types of PMDC motors that are suitable for wind power DC generators include traction motors used in golf carts, fork lifts and electric cars.
- Usually these motors are 24, 36 or 48 volt types with high efficiencies and power ratings.
- One of the main disadvantages of permanent magnet DC generators, is that these machines have commutating brushes that carry the full output current of the generator so DC machines used as dynamos and generators require regular maintenance as the carbon brushes used to extract the generated current quickly wear out and produce a lot of electrically conductive carbon dust inside the machine.
- Therefore, alternators are sometimes used.

- Car alternators are another very popular choice for use as a wind turbine generator, especially among newcomers and DIY enthusiasts as low voltage DC can also be generated by alternators.
- Most automotive alternators contain AC-to-DC rectifiers that supply DC voltage and current.
- In an alternator, the magnetic field rotates and the variable 3-phase AC which is generated by the stationary stator coils is converted into 12 volts DC by an internal rectifier circuit.
- Automotive alternators have the distinct advantage that they are specifically designed to charge 12 or 24 volt batteries.

- One of the hardest parts of designing a small scale low voltage wind turbine for electricity production is to finding a suitable DC generator.
- The **Permanent Magnet DC Generators** is a low speed generator that are pretty reliable and efficient in light winds for use in "off-grid" stand alone systems to charge batteries, or to power low voltage lighting and appliances.
- They generally have linear power curves with low cut-in speeds of around 10 mph.
- Unfortunately, old style permanent magnetic DC generators which are larger, heavier and more robust are becoming more difficult to find.

- As well as permanent magnet DC generators, automotive car alternators are also another popular choice among do-it-yourselfers for low voltage turbine generators, however, they require high rpm speeds and are not always very efficient.
- They also require an external power supply to power the electromagnets that create the internal magnetic field.
- Car alternators limit their own current using a built-in regulator circuit which also stops the alternator from overcharging the connected batteries.
- However, an automotive alternator should never be connected to the battery bank in reverse or run the alternator at high speeds without the battery connected, as the output voltage will rise to high levels (much more than 12 volts) and destroy the internal rectifier.

- Low voltage stand alone wind power DC systems are great for charging batteries etc, but if we want to power larger mains connected appliances or have a system that is "grid-tied" we need to either use some form of inverter to change the low voltage DC generated by the permanent magnet DC generator into a higher voltage (120 or 240 volts) AC supply, or install another different type of wind turbine generator.

- Basically, the *synchronous generator* is a synchronous electro-mechanical machine used as a generator and consists of a magnetic field on the rotor that rotates and a stationary stator containing multiple windings that supplies the generated power.
- The rotors magnetic field system (excitation) is created by using either permanent magnets mounted directly onto the rotor or energized electromagnetically by an external DC current flowing in the rotor field windings.
- This DC field current is transmitted to the synchronous machine's rotor via slip rings and carbon or graphite brushes.
- Unlike the previous DC generator, synchronous generators do not require complex commutation allowing for a simpler construction.

- The synchronous generator operates in a similar way to the automotive car alternator and consists of the two following common parts:
  - The Stator: The stator carries three separate (3-phase) armature windings physically and electrically displaced from each other by 120 degrees producing an AC voltage output.
  - The Rotor: The rotor carries the magnetic field either as permanent magnets or wound field coils connected to an external DC power source via slip rings and carbon brushes.

- When talking about the "synchronous generator", the terminology used for the description of the machines parts is the reverse to that for the description of the DC generator.
- The field windings are the windings producing the main magnetic field which are the rotor windings for a synchronous machine, and the armature windings are the windings where the main voltage is induced usually called the stator windings.
- In other words, for a synchronous machine, **the rotor windings are the field windings** and **the stator windings are the armature windings** as shown.