

EE2029: Introduction to Electrical Energy System

How to Represent Generators Electrically?

Lecturer : Dr. Sangit Sasidhar

Department of Electrical and Computer Engineering

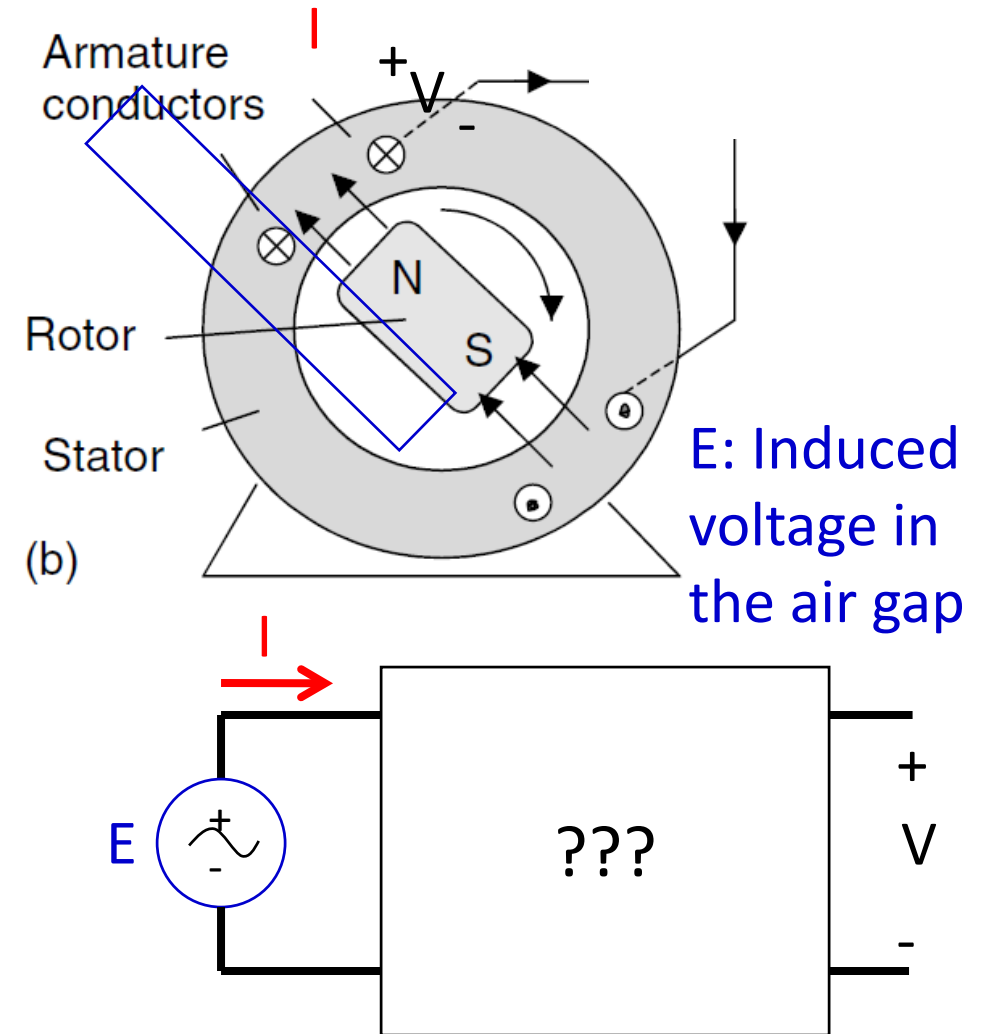


Learning Outcomes

- Excitation voltage
- Armature reaction
- Equivalent circuit of a generator
- Connecting a generator to the grid

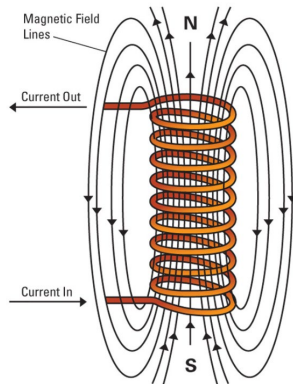
Equivalent Circuit of a Generator

- An equivalent circuit of a generator is given in **per-phase** representation.
 - E = “Excitation” voltage i.e. internal Electromotive force (EMF) voltage (line-to-neutral value).
 - V = “Grid” voltage i.e. terminal voltage (line-to-neutral value). We usually use this voltage as a reference.
 - I = Armature current or load current.

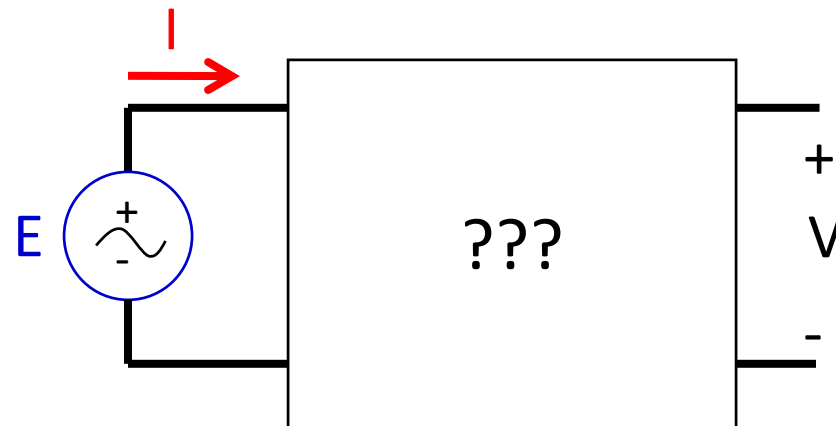


Excitation Voltage (E)

- Excitation voltage (E) or induced EMF is caused by an induced magnetic flux in the air-gap.
 - The magnetic flux on the rotor is created by a field winding at the rotor.



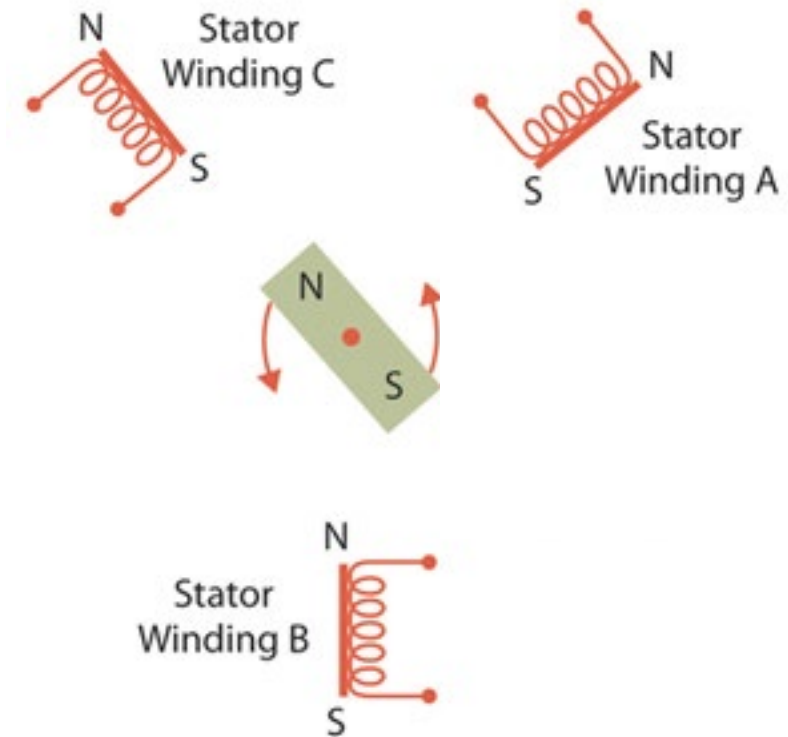
Rotating a
constant
magnetic
field
produces E .



Source:
[http://www.lanl.gov/news/index.php/fuseaction/1663.
article/d/20085/id/13276](http://www.lanl.gov/news/index.php/fuseaction/1663.article/d/20085/id/13276)

Magnetic Flux in the Air-Gap

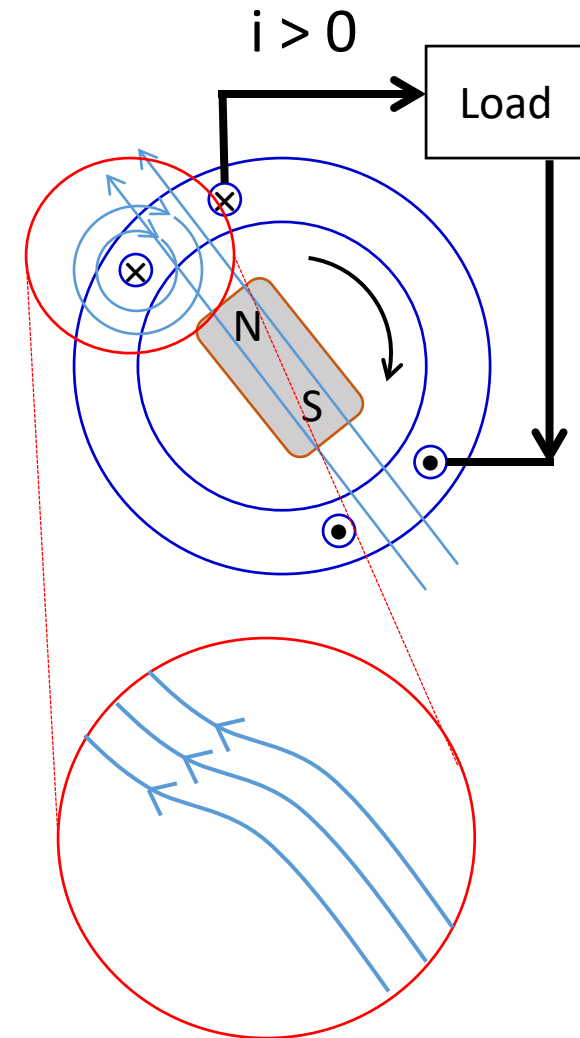
- Magnetic Flux in the air-gap comes from two parts.
 1. Field current in the rotor circuit creates a constant magnetic field around the rotor.
 2. When the rotor turns, there will be induced voltage at the stator winding. After we connect stator winding to load, there will be stator (armature) currents in the stator (armature) circuit. Armature current will also create another magnetic field around it too!!



Source: <http://www.ecnmag.com/article-brushless-dc-motor-control-111609.aspx>

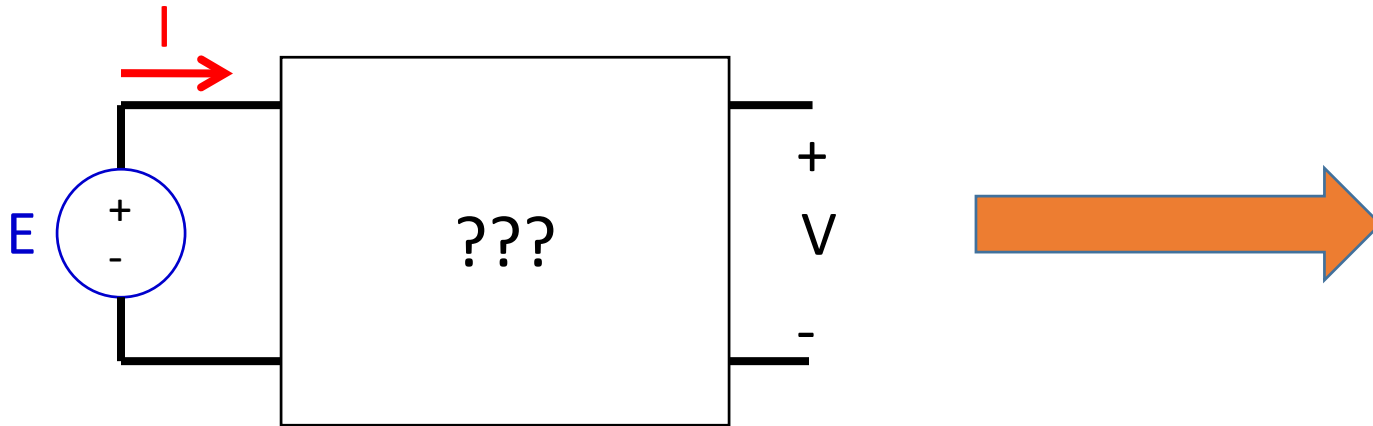
Armature Reaction (X_a)

- Magnetic flux created from stator (armature) currents opposes the magnetic flux from field current.
- Flux linkage losses as a result of armature reaction are represented by an inductance called **armature reactance, X_a** .
- *Note that you can learn more about this topic in EE4502: Electric Drive and Control*



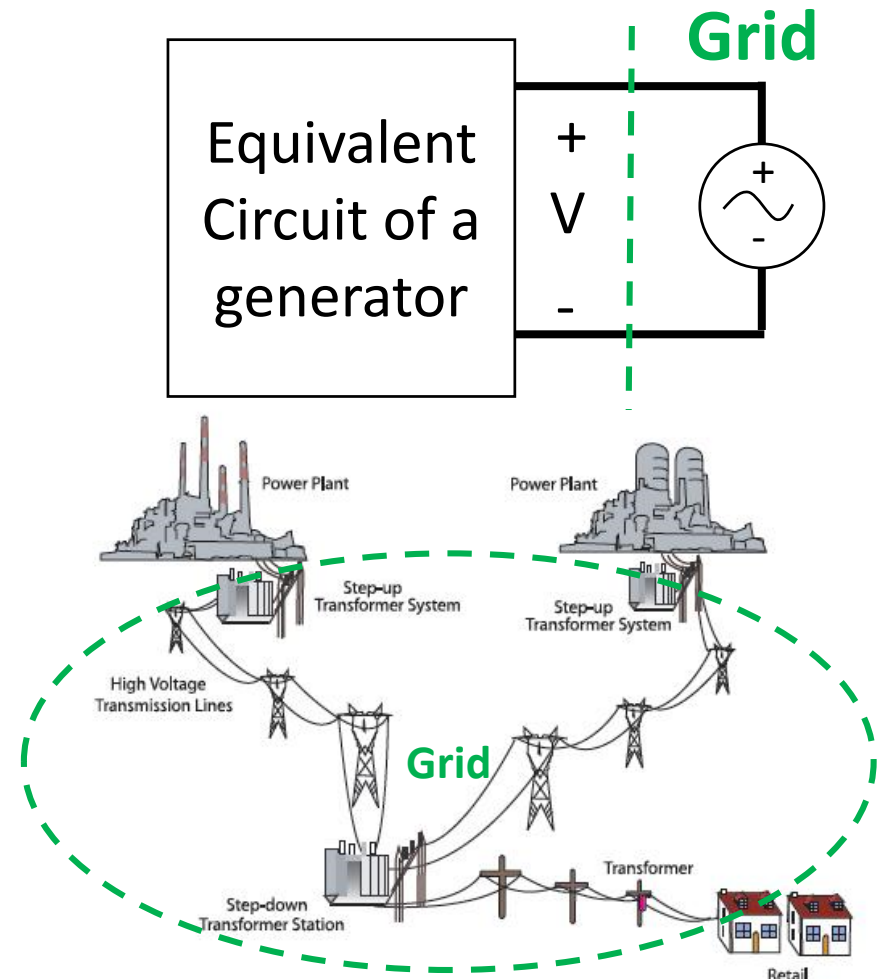
An Equivalent Circuit

- R = resistance in the armature winding.
- X = synchronous reactance, representing flux linkage losses with a leakage reactance in the air-gap, X_l and the armature reaction, X_a .
- E = Excitation voltage or induced EMF is caused by an induced magnetic flux in the air-gap.



Connecting A Generator to the Grid

- Four conditions need to be met before connecting a generator to the grid:
 1. The three-phase voltage must have the same **frequency** as the grid.
 2. The three-phase voltage must have the same **amplitude** at its terminals as the one of the grid voltage.
 3. The three-phase voltage must have the same **phase sequence** as the grid voltage.
 4. The three-phase voltage must be **in phase** with the grid voltage.



Source:

http://www.thermalfluidscentral.org/encyclopedia/index.php/Generation,_Transmission,_and_Distribution_of_Electricity



Summary