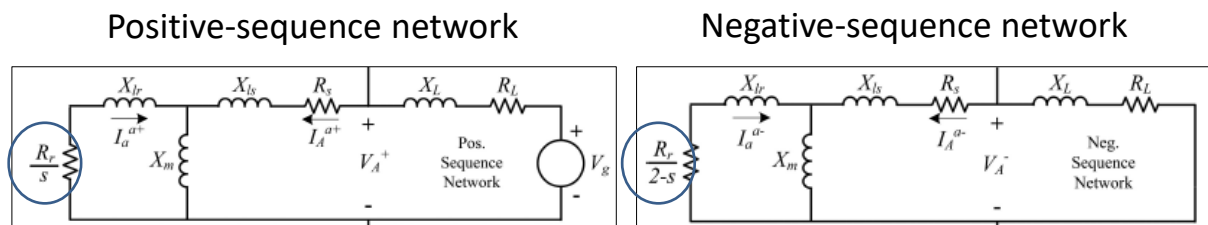


Renewable Energy Sources (RES) introduce changes in the sequence networks :

- RES may remove negative-sequence current injection
- RES create a great non-homogeneity in both positive and negative-pure fault networks and big differences between both networks. The angle of the positive / negative-sequence local source impedance can be far away from 90° due to the following:
 - o Current limitation performed by the converter
 - o Induction machine sequence networks (during crowbar operation), see figure 1 where R_r represent the rotor plus the crowbar resistance. The influence of this resistance and the slip make the angles of both positive and negative-sequence impedances be different from 90° and different from each other



Reference: "Improved Sequence Network Model of Wind Turbine Generators for Short-Circuit Studies,"

Figure 1. Sequence networks of wind generators

The mentioned changes in the sequence networks affects :

- The polarization of the reactance line in distance units :
 - o I2 is not reliable if there is no I2 injection
 - o Even if there is I2 injection, I2 and I1_pure_fault (I1 pre-fault removed) will not be parallel to IF (current that flows through the fault resistance) due to the non-homogeneity of the sequence networks
- Phase selectors based on currents : the angles between the sequence currents will not be the expected ones therefore the current-based phase selectors will fail
- Certain directional units :
 - o Negative-sequence if there is no I2
 - o Positive-sequence if crowbar operates in type 3 wind generator because the machine will start absorbing reactive and active power depending on the slip:

The following solutions have been included :

- New polarizations using a non-homogeneity compensation based on the measurement of the local source impedances
- Phase selector based on sequence voltages
- Directional unit based on positive-sequence voltage and phase currents

It has been checked with simulated and real faults that the new algorithms work well with RES.

Further information can be found in [1] and [2]

References

- [1] A. Castañon, R. Cimadevilla, P. Eguia, E. Torres and R. Ibarra, "Impact of Wind Generation on Line Protection," in *PAC World Conference 2021*
- [2] R. Cimadevilla, A. Castañon "Advanced Phase Selection for Severe Line Protection Requirements" in *PAC World Conference 2022*

