

ASYMMETRICAL WINDING AND PARALLEL CONNECTION

WINDING PITCH

Winding pitch is defined as the ratio between the number of stator slots spanned by each coil and the number of winding slots per alternator pole.

It is one of the key design parameters used to reduce harmonic content in the output voltage waveform.

A **2/3 pitch** eliminates the **3rd harmonic** under normal conditions.

However, there is one exception: **the presence of asymmetrical winding**.

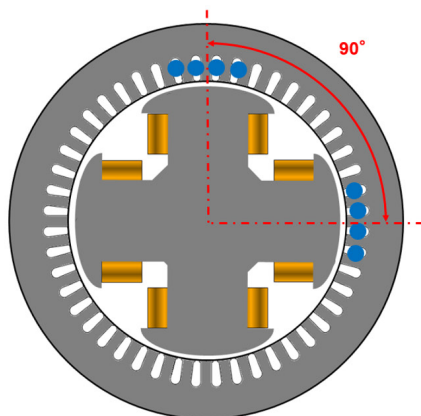


Fig.1: Full Pitch

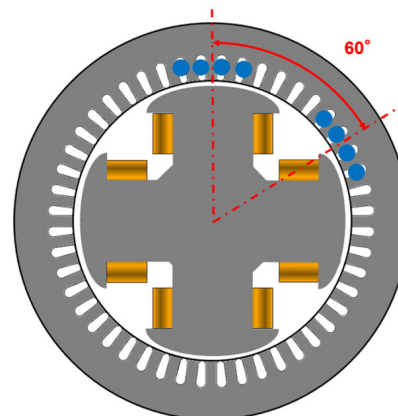


Fig.2: 2/3 Winding Pitch

ASYMMETRICAL WINDING

The number of turns per phase is the main parameter used to optimize a generator for different voltage levels at a given power rating.

A turn is composed of two active conductors: a go conductor and a return conductor, placed in two different stator slots and carrying the same current in opposite directions.

In some cases, the theoretical number of conductors per slot per phase is not an integer. When the value falls between integers, it is rounded to the nearest half-number of conductors

To implement non-integer number of conductors per slot, a technique known as **asymmetrical winding** is used.

This method consists of:

- In a given stator slot, adding one conductor to one of the two phases (U or V) and removing one in the adjacent slot
- In the next slot, performing the opposite adjustment so that the total number of turns per phase remains unchanged (one less for the other phase)
- Ultimately, each phase contains the same total number of turns, ensuring a **balanced fundamental magnetic field**
- As a result, the local magnetic field distribution in some slots becomes slightly unbalanced compared to the surrounding slots
- This asymmetry generates a **third-order harmonic** in each phase voltage waveform, **even with a 2/3 pitch winding is used**

As an example, the diagram below illustrates an asymmetric stator winding with five conductors per slot, arranged according to the following conductor distribution:

Phase U: 3→2→3→2

Phase V: 2→3→2→3

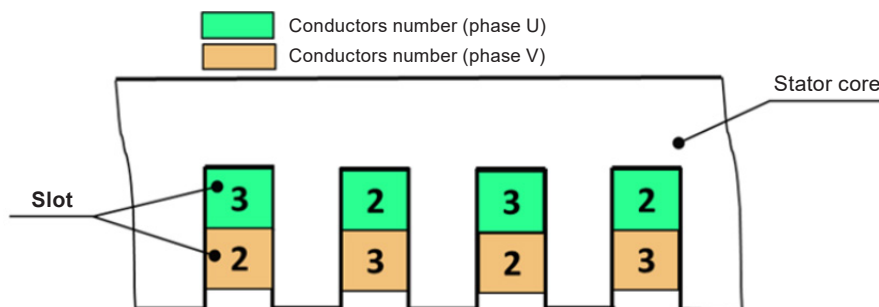


Fig.3: Asymmetric winding

PARALLEL CONNECTION

As demonstrated above, alternators with a symmetrical 2/3 pitch winding do not have the same harmonic profile as alternators using asymmetrical winding.

Therefore, when these two types of alternators are operated in parallel, **and the neutral is connected**:

- Their **voltage waveforms differ**, particularly regarding the **3rd harmonic component**—present in asymmetrical designs and absent in symmetrical ones
- This mismatch leads to circulating currents between the alternators or the grid, independent of the load
- The resulting neutral current flow occurs **three times the fundamental frequency**

This neutral current can become significant when paralleling an asymmetrically wound alternator with another machine having a different winding configuration.

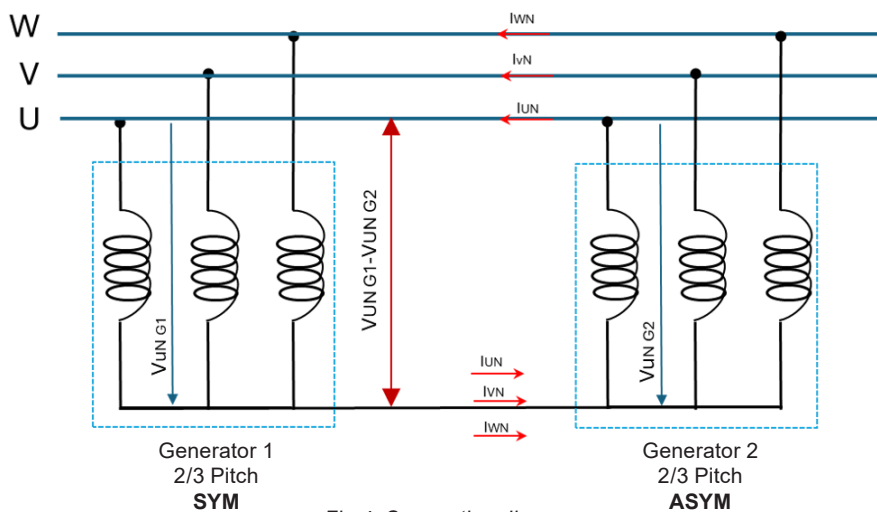


Fig.4: Connection diagram

Under these conditions, the circulating neutral current is expressed by the following equation:

$$I_N(t) = 3 \cdot \frac{(V_{UN G1}(t) - V_{UN G2}(t))}{(Z_{0 G1} + Z_{0 G2})}$$

where $Z_{0 G1}$ and $Z_{0 G2}$ are the zero-sequence impedances of generators G1 and G2, respectively.

Important notes:

- In the rating tables ([see catalogue ref. 6627](#)), asymmetrical windings are marked with an **asterisk** and must be taken into account during alternator selection

RECOMMENDATIONS FOR SELECTION

As demonstrated above, alternators with a symmetrical 2/3 pitch winding do not have the same harmonic profile as alternators using asymmetrical winding.

- For asterisk marked product strictly follow **rating table recommendation**
- Consider selecting the **next higher power rating**
- Use a **neutral choke** when appropriate.
- Request a feasibility study for a **special adapted winding** if needed

RECOMMENDATIONS FOR INSTALLATIONS WITH NEUTRAL CURRENT

If a neutral current exists:

- **If the neutral current is less than 20% of the rated current:**

→ No specific corrective action is required as complied with CEI 60034

- **If the neutral current exceeds 20% of the rated current:**

→ Apply the following measures:

- Parallel only machines with **similar winding pitches** (no neutral to earth connection required)
- **Derate the alternator** to accommodate for the additional neutral current
- Install **neutral chokes** between generators or neutral connection point
- Use **active or passive filters** tuned to the 3rd harmonic

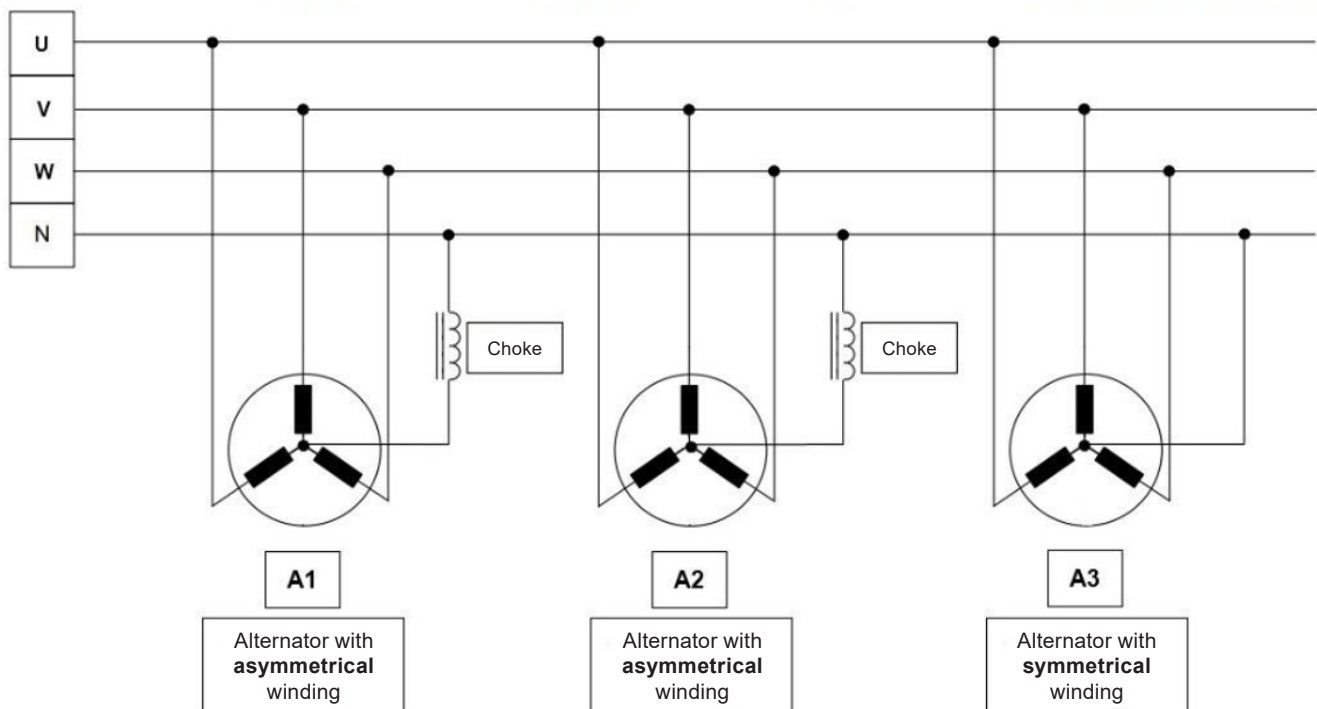


Fig.5: Choke connection to alternators