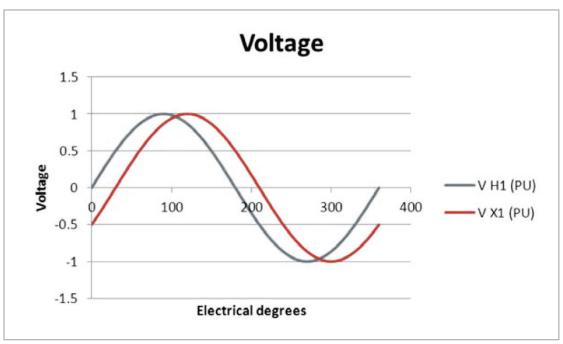
WHITEPAPER

Phase shifting transformers

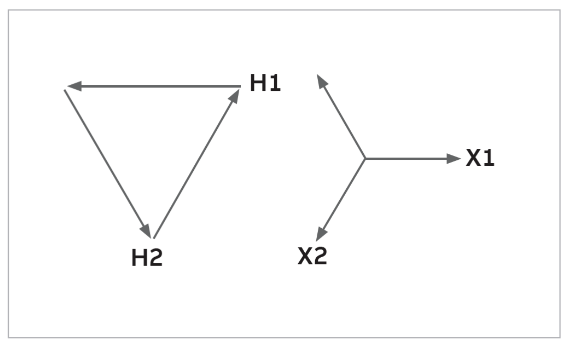
Different transformers connections induce different phase shifting on each harmonic. Considering this, an installation topology could be selected to eliminate specific harmonics due to electrical cancelation at primary's bus.



Two sinusoidal waves have different phases when their peaks do not occur at the same time. The difference in electrical degrees is the phase angle between them. Some transformer connections can induce a phase shift in current. For example, a Delta–Y connection induces a 30° phase shift between the primary and secondary side of the transformer.

When transformers feed non-linear loads, each harmonic is affected in a different way by this phase shift. 0° and 30° phase shifts are important because they cause a 0° and 180° phase shift respectively for the 5th and 7th harmonics.

What is the relevance of this? Let's consider the following case.



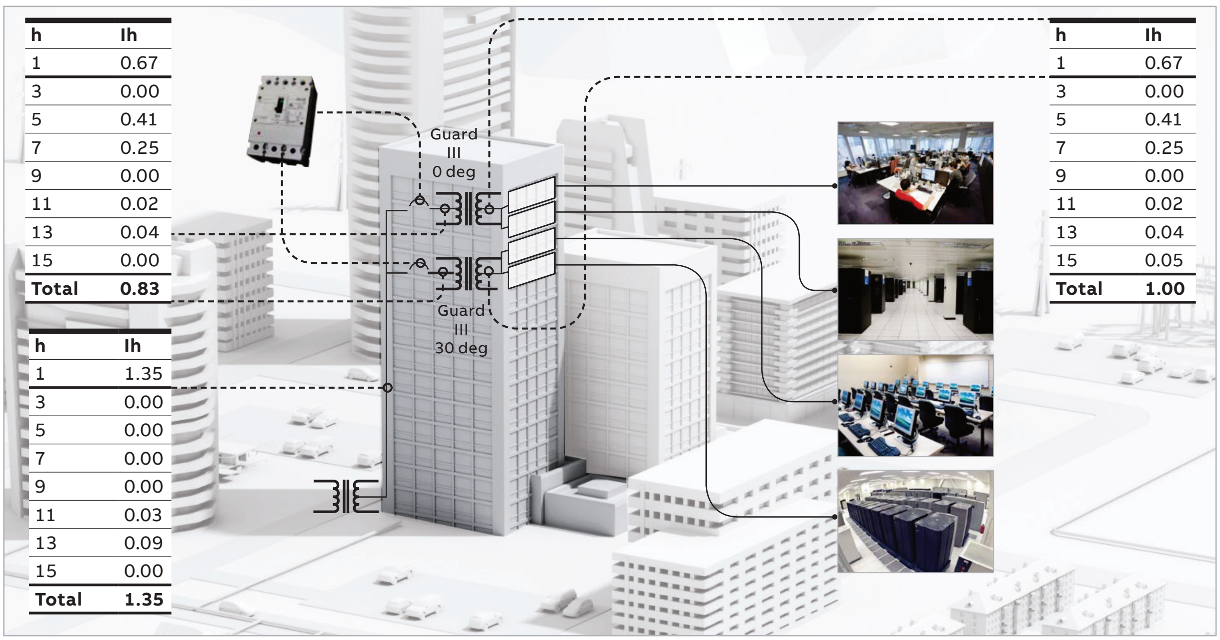
We have a requirement to feed a four-floor data center. Each two-floor space has the same quantity and type of computers working at the same time. We will feed one two-floor space with 0° Guard III transformers and the second two-floor space with a 30° Guard III transformer. The harmonics profile of each transformer load per unit is as follows:

H	Ih
1	0.67
3	0.55
5	0.41
7	0.25
9	0.11
11	0.02
13	0.04
15	0.05
Total	**1.00**

In order to simplify the calculation, the profile is expressed per unit, based on transformer capacity. The profile used is the typical harmonics profile of a single-phase electronic load that has a THD of 109.35%.

As observed, the transformers are feeding rated capacity to the loads. Because they are harmonic mitigating transformers, all harmonic multiples of three are magnetically canceled. This means that on the primary side, the transformers are circulating 0.83 per unit current. The harmonic mitigation has released approximately 17% of the installed capacity at those branches. Additionally, the THD is reduced to 71.23% by the filtering effect.

As stated above, a phase shift induced by the transformers in the 5th and 7th harmonics current results in currents that have opposite polarity, which means that they will be cancelled at the common bus. Due to the elimination of these currents, the total current at this point is 1.35 per unit instead of 2.0 per unit originally demanded by the loads, a 32.5% reduction. On the other hand, the harmonic distortion has been significantly reduced from 109.35% to 6.74%.



h	Ih
1	0.67
3	0.00
5	0.41
7	0.25
9	0.00
11	0.02
13	0.04
15	0.00
Total	**0.83**

h	Ih
1	1.35
3	0.00
5	0.00
7	0.00
9	0.00
11	0.03
13	0.09
15	0.00
Total	**1.35**

h	Ih
1	0.67
3	0.00
5	0.41
7	0.25
9	0.00
11	0.02
13	0.04
15	0.05
Total	**1.00**

The key to achieve this cancelation is balance. Non-linear loads should be distributed to reach an optimum balance in the phases and the transformers involved in the cancelation. Capacity is not the only important factor. The type of load must be considered. Each electronic load has a particular harmonics profile and is required to reach the maximum cancelation effect in the same harmonic profile in each phase of the transformers.

Considerable benefits are reported for this filtering process. If regulation allows it, the current reduction could allow a reduction in conductor size and protection device capacity such as breakers. It could also be considered a release of installed capacity to feed additional loads. Current reduction and the decrease of harmonic distortion means less loss for the system which reduces the thermal stress of the conductors and equipment.

The reduction in the harmonics decreases or avoids the negative effects of harmonics in the power system.

ABB Inc.
305 Gregson Drive
Cary, NC 27511

1TQC1939E0001 REV. A MAR 2020