

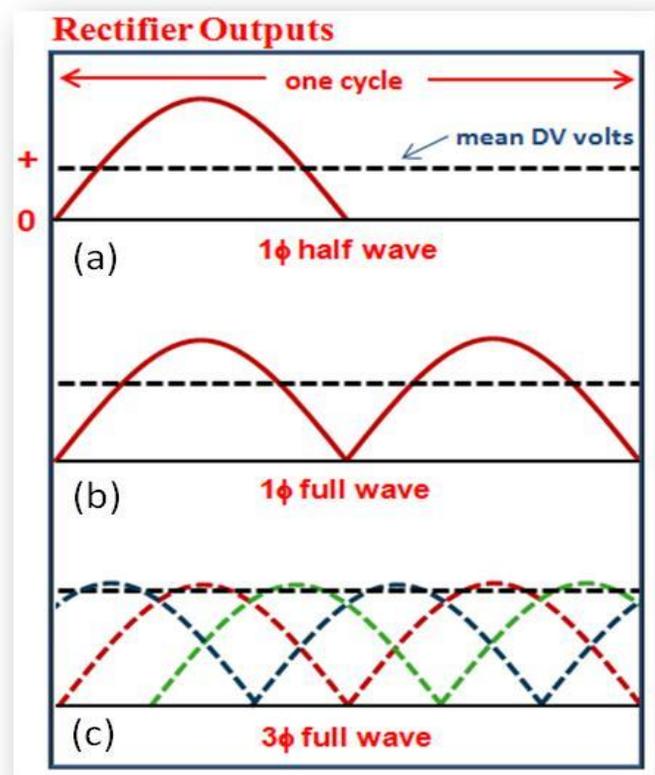
September, 2013

Rectifier Duty Transformers

Transformers play an important role in industrial applications, especially in metallurgical plants and processes. Very high currents need to be supplied for AC and DC electric arc furnaces and ladle furnaces utilized in the aluminum, copper, zinc, chlorine, and carbon industries, as well as for large industrial drives. As production capacities continue to grow on a grand scale to meet worldwide demand, ever increasing voltages and currents need to be supplied via larger and more powerful transformers. The environments in which the transformers supply power for such processes can be quite severe. Transformers exposed to high cyclical loads and thermal stresses must be able to withstand frequent overcurrents and overvoltages caused by short circuits and/ or tripping of high-voltage circuit breakers. “Off the shelf” transformers simply are not appropriate for such applications. Rectifier duty transformers must be specifically designed to manage the load profile thereby insuring uninterrupted and reliable output.

The method of rectification is referred to by counting the number of DC “pulses” output per 360 degree cycle. A single-phase, half-wave rectifier circuit (a) is referred to as a 1-pulse rectifier. A single-phase, full-wave rectifier (b) is called a 2-pulse. A three-phase full-wave rectifier (c) is a 6-pulse (2 pulse per phase x 3).

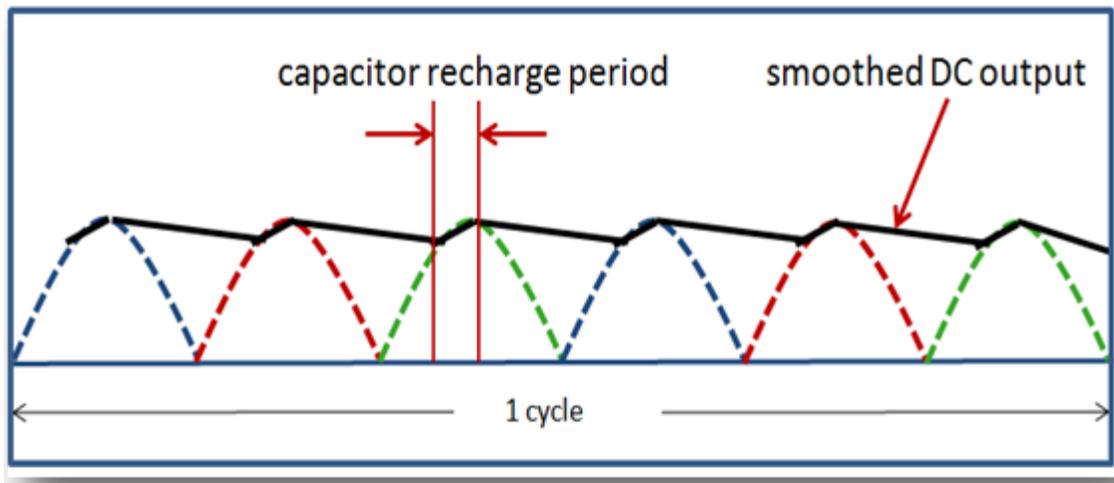
Note in the diagram to the right that increased pulses per cycle equates an increase in the mean DC voltage output.



Pacific Crest Transformers

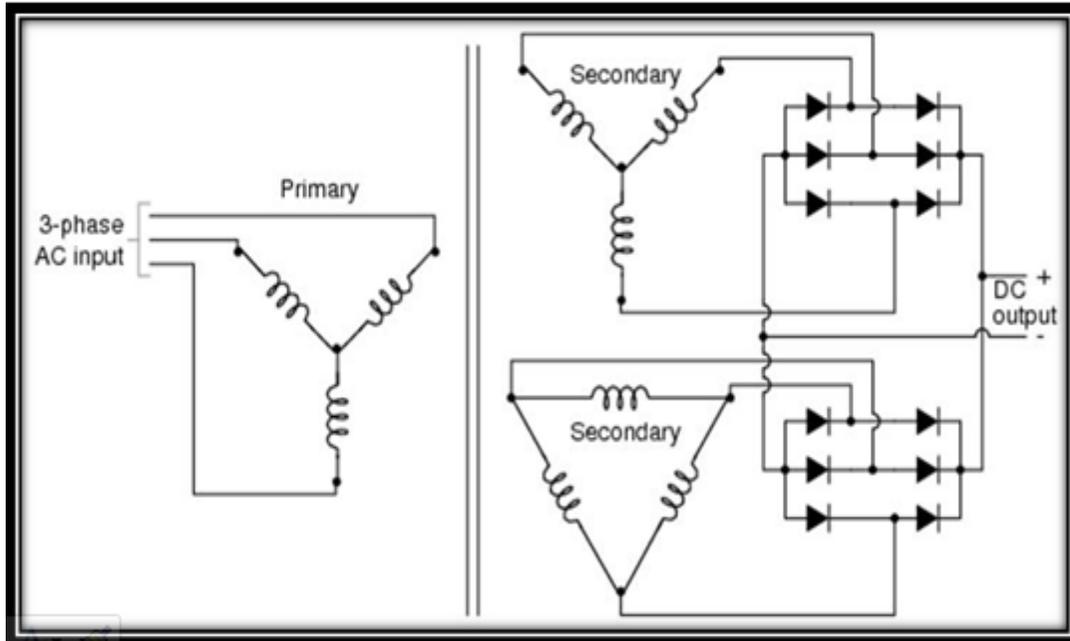
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Whether single or polyphase rectification, the amount of AC voltage mixed with the rectifier's DC output is called ripple voltage. By employing smoothing capacitors in the rectifier circuit, ripple voltage can be minimized.

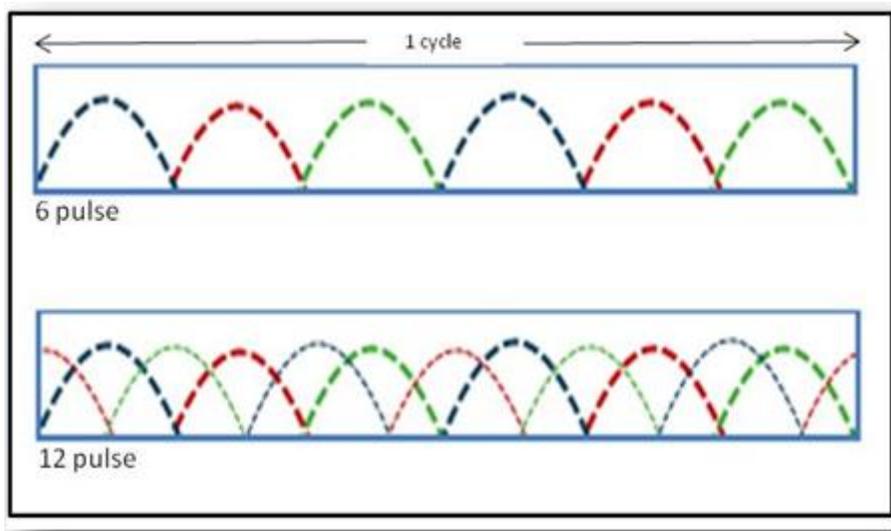


As the diagram above reveals, an increase in pulses per cycle provided by a 3 phase, 6 pulse transformer output coupled with filtering capacitors dramatically reduces the ripple effect.

To further improve the DC output, sets of full-wave rectifiers may be paralleled in such a way that more than six pulses of DC are produced for three phases of AC. A 30 degree phase shift is introduced from primary to secondary of a three-phase transformer when the winding configurations are not of the same type. In other words, a transformer connected either wye-delta or delta-wye will produce a 30 degree phase shift, while a transformer connected wye-wye or delta-delta will not. By employing a transformer with 2 separate secondary windings, one connected wye and one connected delta, 2 bridge rectifiers can be fed. The DC outputs of both rectifiers can then be connected in parallel (see below).



Since the ripple voltage waveforms of the two rectifiers' outputs are phase-shifted 30 degrees from one another, their superposition results in less ripple than either rectifier output considered separately since the output has now been increased from 6 pulse to 12 pulse (see below).



Additional smoothing can then be had via the use of smoothing capacitors

Rectifier loads tend to be non-linear with large distortions due to harmonic loading on the system thereby causing wave form distortion. The amount of harmonic loading and resultant wave form distortion varies with the source impedance, rectification smoothing, and power output. Wave form distortion from harmonic loading can be significantly reduced however by utilizing a 12 pulse transformer which limits the impact of 5th, 7th, and 11th harmonics due to the 30 degree phase shift from the additional secondary windings.

Whether 6 pulse or 12 pulse, rectifier loads must be accommodated for in the transformer core/coil design. Non-sinusoidal loading can lead to localized coil heating. Radial and axial forces due to heavy loading and short circuits must be accommodated.

The utilization of round coils with cruciform stacked cores allows for 360 degree coil cooling thereby minimizing hot-spots. Round coils also effectively manage radial forces since they are equalized throughout their circumferences. Management of coil heating and radial movement protects the winding layer insulation system from premature aging and rupture.



Axial forces must also be managed, especially during fault conditions. Failure to do so can lead to telescoping of the coil turns which in turn results in coil failures. Round coil construction coupled with cruciform stacked cores provide for the capability of adding pressure plates to the top and bottom of each coil.

The pressure plates have numerous routed ducts which allow for unrestricted flow of the cooling fluid. Metal all-thread bolts secure the top and bottom pressure plates thereby providing protection against coil movement due to axial forces.

The upper photo shows a complete core/coil assembly for a 6 pulse rectifier feed transformer. The lower photo shows a 12 pulse unit with 3 upper and 3 lower coils. The primaries for each set are paralleled to form a single 3 phase input while the 2 sets of secondary windings are arranged with one set wye connected and one set delta connected. The outputs from the secondaries provide input to the 2 bridge rectifiers.



As with all products produced by Pacific Crest Transformers, strict attention is paid to the details as pertains to the application and duty cycle for each transformer provided. Specific design parameters are utilized for specific needs. There is far more to specifying a liquid filled transformer than mere kVA and voltages. Although all transformers must meet ANSI construction and test

standards, the optimum design needs to take into consideration the application and operating environment of the installed transformer to insure optimum performance as well as long term operation.

Pacific Crest Transformers: Providing innovative solutions for today's complex challenges