

## SCR Timing and The Zero Crossing

### General

The key to designing a successfully working tap switching voltage regulator is the number of taps and the electronic method used in switching them. The 7-tap design of the Power Processor utilizes the most advanced method for efficient tap switching. Knowing when and how to switch taps on a voltage regulator is a crucial design

consideration. The performance and proper operation of the unit and the load depends on it. In the world of tap switching voltage regulators, most manufacturers use Silicon Controlled Rectifiers (SCRs) to switch taps on their transformers, which is the preferred method, but there are some who use contactors: these are

disastrous. If SCRs are used and the timing of the firing of the SCR is not correct, then you will have an ineffective system that will not regulate properly. The key to having a good tap-switching regulator is to make sure that SCRs are used and they are gated at the correct point on the sine wave.

### Why Only Use SCRs?

To regulate voltage using a tap switching technology, a signal is required from a detection circuit in order to invoke a device that will cut current from one winding of a transformer and allow current to flow to another winding on a transformer. This can be accomplished many ways; one of these ways is by the use of a contactor. Contactors usually have a switch time of around 12ms - 20ms; so once the detection circuit says, "switch to another tap" it will take approximately 12ms to open

the contactor. During this time the output voltage will fall for approximately 1 cycle. This will result in a de-excitation of the transformer and/or drop the load. Once the detection circuit of the regulator initiates the closure of another contactor so that current will flow through another tap, another 12ms will transpire. Now power is dropped on the output for 24ms(at best), but that is not the only problem. Once the second contactor closes, the transformer needs to be re-energized; this produces a

surge current that can reach up to 20x the average current of the system. This type of current causes abnormal tripping of circuit breakers and unwanted system stress. The proper method of switching taps is to use a microprocessor control and SCRs. SCRs do not have the long switch time that contactors do, in fact they're seamless! There is no de-excitation of the transformer, no drop of the load, and no surge current, it is the ideal component for the job!

### Point of Firing and the Zero Crossing

Making sure your voltage regulator uses SCRs to switch taps is crucial, but if they are not gated at the correct point on the waveform other problems will occur. For an ideal voltage regulator the SCR must be gated when there is no current passing through the system. The only point that this condition can occur at is at the zero crossing of the

sine wave. For detecting the zero crossing, most power conditioning manufacturers use a CT (current transformer) or a Hall Effect transducer. Do these devices work? Both devices do detect the zero crossing of the waveform, but they have their problems. Since both hall effect transducers and CT's are just active and passive devices, they have a

time constant. This time constant results in a phase shift of the sensing current resulting in a delay in the firing circuit. Once a zero crossing is detected and the microprocessor determines the need for a tap change, a message is then sent to a gating circuit indicating that it is time to turn on another SCR and allow the existing SCR to commutate. This is

where CTs hall effect transducers lose their luster. Since there is a delay, when the firing circuit receives the message to switch SCRs, a considerable amount of time has transpired. Most systems will have a delay of about 6-8 degrees after the zero crossing before the SCR will turn on. So what happens? 6-8 degrees of delay on a 208V waveform is equal to a 400 - 600 $\mu$ s blackout, this may not seem like a lot but it is equal to a 30-40V drop in the output voltage. Figure #1 below is a representation of

what the output waveform could look like. Depending on the sensitivity of your equipment, this momentary loss of power can be disastrous. I thought regulators were supposed to correct these things! Does the Power Processor use CTs or Hall Effect Transducers? The answer is no. The Power Processor uses a linear, analog detection device, which invokes a gating device to send a signal to the SCR to switch with high precision close to the zero crossing. How high is the precision?

Delay times on a Power Processor is about 2 degrees or 139 $\mu$ s. Figure #2 below is a representation of the Power Processor's output waveform; When comparing this waveform to the other, there is a noticeable difference. The voltage loss on a 208V system is only 10V, which is negligible since most sensitive systems can handle a less than 5% excursion of the input voltage. Virtually undetectable and safe for all sensitive electronic loads!

Figure #1

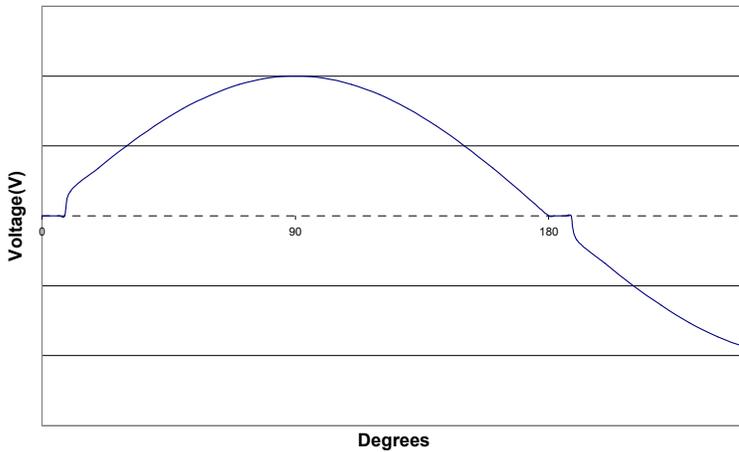
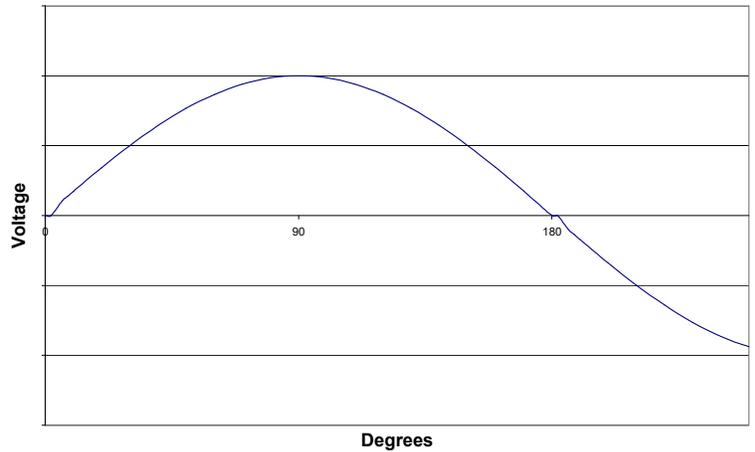


Figure #2



## Notching and Short Term Blackouts

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Notching and short term brownouts can be detrimental to your load if your tap switching voltage regulator is not properly designed to handle them. Most tap switching voltage regulators monitor the input or output voltage and then when a high or low voltage condition is detected, one SCR will turn off and another will turn on, thus switching taps. Most tap switching systems will send only one signal to the gate of the SCR to turn it on. This is fine if we lived in a world of perfect power. If a short-term brownout occurs and causes

the current to fall to zero, then the SCR will commutate. This results in a loss of power at the load. If a notch occurs, regulators may switch taps prematurely resulting in an over correction of the input voltage. This results in loss of regulation.

The Power Processor uses a different form of technology called Digital Averaging. Digital Averaging is a technology that insures the SCR will stay on it's proper tap even in a notching or short term blackout condition, thus keeping the

power conditioned at the load.

On many tap switching regulators if a notch occurs on the system, then the current flowing through the SCR will fall close to zero resulting in a premature commutation of the SCR. This in turn will cause a temporary loss of power. The Power Processor has solved this problem. In the event that a notch occurs in the system, the Power Processor insures that the proper SCR will stay on by means of continuous high frequency gating.

## Summary

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Knowing when and a voltage regulator should switch taps is a key factor in the proper performance of the regulator. To select a good tap switching regulator, the regulator must be of an SCR type and not use contactors for switching taps. Contactors have a long switch time, resulting in de-excitation of the transfer and possible momentary blackouts. SCR's however, do not have a long switch-time and are the preferred component for the system. For a tap switching voltage regulator to operate effectively, SCR's must fire at

or very near the zero crossing. Most tap-switching regulators use current transformers or Hall Effect Transducers to detect a zero crossing on the input waveform. These two devices are comprised of active and passive electrical circuitry which have an excessively long delay. This delay causes an inaccuracy in the detection of the zero-crossing resulting in a momentary power loss on the output. The Power Processor does not use CT's or Hall Effect Transducers to detect the zero crossing. The Power Processor uses a

linear analog detection device to successfully switch taps at a zero crossing with virtually no delay. Most tap switching regulators have problems adjusting to notches and short term brownouts. They either over correct or under correct based on the input power. The Power Processor however does not have this problem. The Power Processor uses a technology called Digital Averaging; this insures that the regulator maintains proper output regulation regardless of short term blackouts or notches.