# TECHNICAL BULLETIN:
# VOLTAGE REGULATION AND FLICKER CONTROL USING VECTEK IGBT STATIC VAR COMPENSATORS

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## Introduction.

Some industry processes such as induction and arc furnaces, car crushers, mine machinery, and others present large fluctuating loads to the supply. These fluctuations cause small variations on the supply voltage at the point of common coupling to other users. While the voltage variation may not be large in magnitude it is sufficient to cause the output of electrical lights to fluctuate or flicker. This effect can cause significant annoyance to other users and must be kept below the threshold of awareness.

So why worry if the fluctuations are small? The issue is that much of the lighting used in commerce, residential, and industry is very non-linearly sensitive to voltage and slight variations in voltage give rise to noticeable changes in illumination (hence flicker). Moreover, people are very psychologically poorly disposed to flickering lights with greatest sensitivity occurring around 5-9Hz. The Pst measure uses a weighted scale to model both lighting and human response such that a value of 1 is just discernible and above that becomes progressively annoying (possibly dangerous if you are epileptic). A Pst of 1 roughly corresponds to 0.5% voltage variation at the most sensitive region (5Hz or so). This is not a large variation but it is rapid so is difficult to solve using normal power system solutions.

The solution lies in the use of high speed IGBT inverter based shunt connected voltage regulators. A inverter based active VAR source is effective in combating flicker because it can modulate the current flowing in the supply very quickly at sufficient scale to create a correction voltage on the supply impedance. The inverter will update the current flow many times per cycle giving effective control. It can also manage the available VARs to optimise the PST (rather than just the % variation) and to limit the impact on protection systems fault currents.

## Cause of Voltage Variations.

When a load is connected to the power system it will affect the voltage observed by others on the network. This is because the current drawn will pass through the supply impedance common to other users, and a voltage change will occur. Of course this voltage drop will generally be small (less than 1% or so) so will not cause any problems with most loads. Even if the voltage drops become significant tap-changing transformers are commonly used to correct the variance. However when the load current is constantly changing then problems of flicker occur. The fast variations cannot be corrected in time by tap changing transformers and the level of variation is often within the switching thresholds anyway.

The connected load current has a component which is in-phase with the supply voltage. This is commonly termed the real component and is the source of the power delivered to the load. This is normally the useful component. The other component is entirely out of phase with the voltage and is often called the reactive or imaginary component. It has a function, usually exciting reactors and machines and facilitates the transport of the power, but has no direct contribution to the real power consumed in the load. In some circumstances the reactive current flow can dominate the current and can transiently assume very large values (eg large motor starting). The supply will always have an impedance created by the supply transformers and the distribution lines and comprises a reactive component (normally inductive) and a resistive component.

The voltage variation caused by the load current flowing through the source impedance is given by the following expression:

$$\Delta V = -(re(I).Rs + im(I).Xs) + j.(re(I).Xs - im(I).Rs)$$

where *re(I)* is the real component of the load current and *im(I)* is the reactive component of the load current. Rs and Xs is the source resistance and reactance respectively.

Note that the fundamental voltage drops only are considered here as the flicker phenomena is a low frequency effect from a voltage drop perspective.

The first term in the expression above dominates the magnitude variation as it is in-phase with the supply. The second term creates some phase shift but does not affect magnitude significantly. It is clear that for a supply which has a dominant inductive source impedance (X/R > 3) the voltage changes will be dominated by variations in the reactive component in the current. The real current component variations will have a secondary effect.

**Solution using an active VAR source.**

A solution to the voltage fluctuations described above is to provide a mechanism to moderate the changes in the reactive current by providing a source of VARs (reactive volt amps) which is continuously variable and capable of adjusting at a rate matching that of the load. The VECTEK PFC Var source is capable of this.

The Var source is connected in shunt to the system preferably as near to the offending load as possible. This provides the greatest localisation of any voltage flicker. The controller measures the supply voltage as a vector comprising instantaneous magnitude and phase and uses the wide bandwidth of the IGBT inverter to control the current vector it introduces into the supply. The in-phase component of the current is controlled to simply supply the small losses in the converter, but no appreciable power is drawn. The out-of-phase current is directly controlled to regulate the voltage magnitude in a closed loop control. As flicker control is the principle objective the steady state voltage error can be ignored and the response limited to the transients. It is also possible to use the var source to supply some steady state Vars for power factor correction albeit at the expense of a reduction in flicker Var capacity. Note that the Var source can supply both leading and lagging Vars and can be combined with lower cost fixed var-sources such as synchronous-condensors or capacitors to extend the capacity in some cases where the var demand is asymmetric (eg. Motor starting or power factor control).

**Sizing**

Sizing is important and is defined by the level of the disturbance, the frequency distribution, the target PST range, and the source impedance. Accurate calculations can reduce costs very significantly and the modular nature and electronic flexibility of an inverter system assist significantly in achieving a good technical and economic fit with the problem and a path for adaptation to changing power system and load characteristics.

**Conclusion**

Some large dynamic loads create appreciable voltage variation in the supply. While the voltage fluctuations are often only a few percent in magnitude they are sufficient to modulate the light output of many standard luminaries and occur at frequencies which cause irritation to others on the network. An effective solution in many cases is a fast acting active Var source based on modern IGBT inverters such as the VECTEK PFC controller. This device can continuously and rapidly modulate reactive current injected into a network to compensate for the variable reactive loading from the load without consuming significant power. The active nature of the source obviates the concerns with system resonance and overloading while providing flexibility to accommodate future changes to the system and load.