

# UNDERSTANDING TRANSIENT REACTANCES

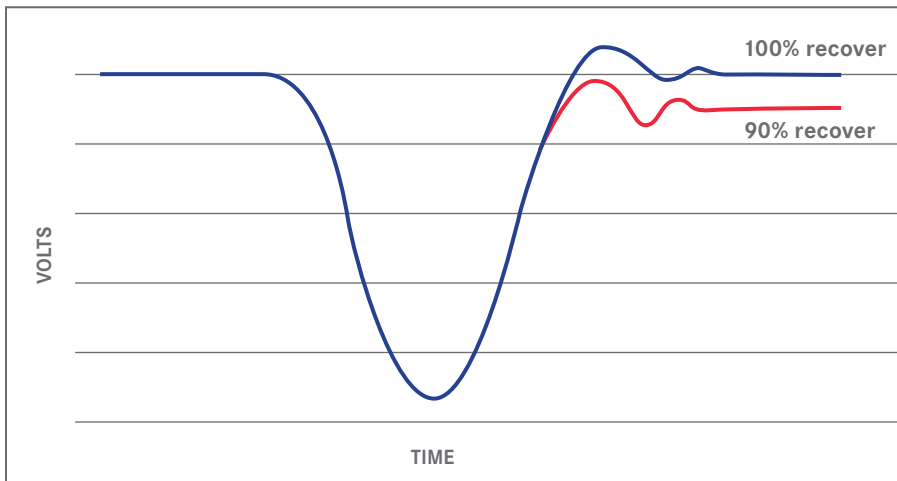
## GENERATOR SET STARTING COMPARISONS MADE EASY



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Power generation systems consist of numerous components, each playing a specific role in providing reliable power to consumers. The manufacturer specifications for these systems are intended to clearly state the values and functions of components to ensure reliable operation for a given application. However, these specifications often omit key information or may state requirements in a confusing manner. One of the best examples of this is when looking at the transient performance of gensets in situations such as starting large motor loads. Clear communication of genset performance is the key to ensuring the customer receives what they need for their specific application, but the relevant information is often buried in confusing terminology.

A typical transient voltage dip upon load application is pictured in Figure 1. This trace shows the RMS (root mean square) phase voltage of the generator set output. When a large load is applied suddenly to the electrical output, the voltage decreases. This decrease in output voltage is caused by a large inrush of current needed to energize the load electrically, which is also known as starting kVA or skVA. This phenomenon may be observed in a home when a vacuum cleaner is started and the lights dim for a brief moment.



The voltage regulator sees the voltage decrease and attempts to increase the output voltage back to rated voltage by increasing the excitation power. Several system factors may affect a given transient voltage trace:

- **Pre-load on the genset:** having load on the genset before applying additional load alters the system's excitation levels and thus the electrical response to transient events.
- **Load type:** systems may respond differently to single large loads versus grouped block loads.
- **Power factor of the load being applied:** the lower the power factor, of the applied load, results in a larger voltage dip.
- **Prime mover speed:** reduced speed may briefly lower the output voltage. Although the engine performance will impact the voltage dip, this paper will only cover generator performance at constant speed to keep the comparisons simple.

**Figure 1:**  
Voltage transient event example



Your local MTU Onsite Energy distributor can help ensure that your generator set performs as expected.

## CLOUDING THE PICTURE

Power system performance includes a large number of variables. Confusion regarding transient performance may be caused by the variety of phrases that manufacturers use to try and distinguish their machinery from the competition. Some of these phrases include:

- **Maximum instantaneous voltage dip:** this describes the largest decrease in voltage that happens the moment after a load is added to the electrical bus.
- **Sustained voltage dip:** this statement refers to the voltage level that the generator set recovers to sometime after a large load is applied.
- **XXX skVA/kW @ 30% voltage dip:** this statement attempts to simplify the relationship of how large a load can be started for a given voltage dip by using a ratio.

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*Clear communication of genset performance is the key to ensuring the customer receives what they need.*

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One may ask, “How do I make a clear decision in the midst of all this information?” What really matters is system performance. The equipment must provide the proper electrical output for a given application.

Some manufacturers state a recovery to 90% rated voltage as a *sustained voltage dip*. This arises from a small excerpt guiding minimum performance per NEMA MG1 part 32, which states: “The generator set shall be capable of recovering to a minimum of 90% of rated no load voltage following the application of the specified kVA load at near zero power factor.” A manufacturer can state a higher load acceptance if they use the sustained voltage dip method as a basis. This sustained voltage dip method of specifying equipment doesn’t account for the initial inrush of electrical power needed for the instantaneous dip. This can be misleading, and one could argue that a properly designed generator set will recover to 100% rated voltage. Rated voltage is one key performance criteria the customer is paying for and should receive. Some loads on a power system are able to operate at less than rated voltage for a sustained period of time, such as induction motors. However, many loads on today’s power systems are sensitive to operating voltage and must be provided rated voltage for proper operation. Datacenter servers and medical scanning equipment are two such loads that may shutdown, lockout or be damaged by sustained voltage dips. Clear communication of generator set performance is the key to ensuring the customer receives what they need for their specific application.

Other manufacturers may publish a ratio such as *XXX skVA/kW @ 30% voltage dip*. This is similar information to the maximum instantaneous voltage dip statement, but it convolutes the usefulness for a given application with ratios, skVA and a high voltage dip. The ratio of skVA/kW does provide a smaller number to look at, but doesn’t provide direct correlation to genset system performance. Furthermore, an elevated high voltage dip, such as 30%, may not even be applicable to the required power system performance for an application. If the system requires a maximum voltage dip of 20%, for example, any amount of skVA above that seen on a datasheet is useless. Once again, clear communication of genset performance is the key to ensuring the customer receives what they need for their specific application.

## A CLEAR ANSWER

The transient response needs to be accounted for and compared between equipment suppliers in an equivalent manner. Here is the secret to making it simple: focus on the unsaturated transient reactance ( $X'_d$  unsat) when making generator comparisons. Reactances are used to describe the operation of a generator's behavior for specific situation during a given period of time. The transient reactance ( $X'_d$ ) is used to describe generator performance during transient events such as large load applications. While manufacturers can use marketing tactics regarding voltage dip to make them appear to be different, reactances provide an agreed standard and consistent way to compare one generator to another, regardless of the manufacturer.

The equation below can be used to show that for a given machine rating (same kVA, same voltage, same frequency), the lower the  $X'_d$ , the lower the amount of voltage dip for an applied load. This is based on physics and holds true for all generator set manufacturers.

In summary, there are many ways to market a machine to make one appear better in performance than the other. However, the customer is at risk of making a misguided decision if the marketing tactics are not comparing equal terminology

Don't forget these keys to unlock the mystery of voltage transients due to starting large motor loads:

- Properly designed equipment meets the customer's needs.
- Clear communication of generator set performance ensures the customer receives what they need for their specific application.
- Proper power system designs recover to 100% rated voltage after a load is applied.
- The instantaneous dip is strictly a function of generator transient reactance ( $X'_d$ ) for a specific applied load (as seen in the NEMA voltage dip equation).

MTU Onsite Energy recommends comparing reactances of different generators along with the NEMA voltage dip equation to make sure that the performance will be comparable and the customer's needs will be met. Call your local MTU Onsite Energy distributor anytime for help.

$$\text{Voltage dip} = \frac{X'_d}{X'_d + \frac{\text{rated kVA}}{\text{starting kVA}}}$$

Where:  $X'_d$  = direct axis transient reactance, per unit.  
Voltage dip equation per NEMA MG-1 32.18.5.3

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