**Technical Paper**

# Improving the Power Quality of UV Systems

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## Introduction

Ultra-violet (UV) disinfection is being widely accepted as a replacement for chemical processes in wastewater treatment plants. UV systems commonly feature high voltage lamps and capacitors. These elements can draw input currents with high total harmonic distortion (THD) at leading power factors, which must be addressed to meet power factor and IEEE-519 harmonic requirements.

Traditionally, wastewater plants loads were dominated by high horsepower line connected pumps that drew lagging current with negligible harmonic distortion. These lagging, linear loads reduced the overall total demand distortion (TDD) at the plant input. These motor loads also kept the overall power factor of the load close to unity by consuming the leading VARs generated by the UV systems. These factors helped the wastewater plant to comply with IEEE-519 harmonic standards as well as operate properly with backup generators.

Pumps fed by variable frequency drives (VFD) are replacing most line connected pumps in wastewater plants for retrofits and new construction. This is driven by the gains in energy efficiency and process control. Commonly used six pulse VFDs draw high harmonic currents from the input at almost unity power factor. As VFD loads become a higher percentage of the total plant load IEEE-519 compliance is increasingly challenging with passive filtering solutions alone. Active filtering solutions are being more commonly applied in wastewater plants. The elimination of the base linear motor loads has also highlighted the power quality of the UV systems – high harmonic currents and a low, leading power factor. One solution is to integrate active filtering into these systems, so they are do not adversely affect the overall IEEE-519 compliance of the plant. By making each UV system IEEE-519 compliant, this approach allows the UV equipment manufacturers to decouple themselves from other power quality compliance issue that may exist in the plant.

## Baseline UV system power quality

Baseline measurements were carried out on a UV system installed in a wastewater plant in the western United States. The UV system input supply was 480V, 60Hz, three phase, three wire. The system has three power set points – High, Medium and Low. Relevant power quality data at these operating points is shown in Table 1. Each power setpoint has a THD greater than 30% and a leading power factor below 0.9.

## Model

An average time domain modeling tool – HAPro was used to develop a model of the UV system. The results from the model are shown in Table 1Table 2. The percentage difference between the model results and the actual measurements are shown in additional columns. The predictive accuracy of the model is confirmed as these errors are relatively small.

*Table 1: Measured Data from UV system*

| Power setting | High | Medium | Low |
|---|---|---|---|
| Input Current (Amps) | 285 | 240 | 185 |
| Input Power (KW) | 205 | 169 | 121 |
| Input kVAR (+ indicates leading) | 109 | 101 | 87 |
| Total Power Factor | 0.83 | 0.81 | 0.78 |
| Displacement Power Factor | 0.88 | 0.86 | 0.81 |
| Total Harmonic Distortion - RMS | 34% | 32% | 31% |
| Harmonic Current (Amps) | 97 | 77 | 57 |
| Capacitive current (Amps) | 131 | 121 | 104 |
| Required corrective current (Amps) | 163 | 143 | 119 |

*Table 2: HAPro model results and comparison to measured data*

| | Model Output | | | Model error | | |
|---|---|---|---|---|---|---|
| Power setting | High | Medium | Low | High | Medium | Low |
| Input Current (Amps) | 282 | 233 | 176 | 1.1% | 2.9% | 4.9% |
| Input Power (KW) | 207 | 169 | 121 | 1.0% | 0.0% | 0.0% |
| Input kVAR (+ indicates leading) | 112 | 96 | 81 | 2.5% | 5.2% | 6.5% |
| Total Power Factor | 0.83 | 0.82 | 0.78 | 0.0% | 1.2% | 0.0% |
| Displacement Power Factor | 0.88 | 0.87 | 0.83 | 0.0% | 1.2% | 2.5% |
| Total Harmonic Distortion - RMS | 34% | 32% | 31% | 0.9% | 0.0% | 0.0% |
| Harmonic Current (Amps) | 95 | 77 | 55 | 2.0% | 0.3% | 4.9% |
| Capacitive current (Amps) | 134 | 115 | 98 | 2.5% | 5.2% | 6.5% |
| Required corrective current (Amps) | 164 | 138 | 112 | 0.9% | 3.6% | 6.1% |

Time domain waveforms of the input current from the UV system and the model are shown in Figure 1 and Figure 2 respectively. A close inspection of these waveforms shows good correlation of the harmonic peaks between the measured and modeled currents.

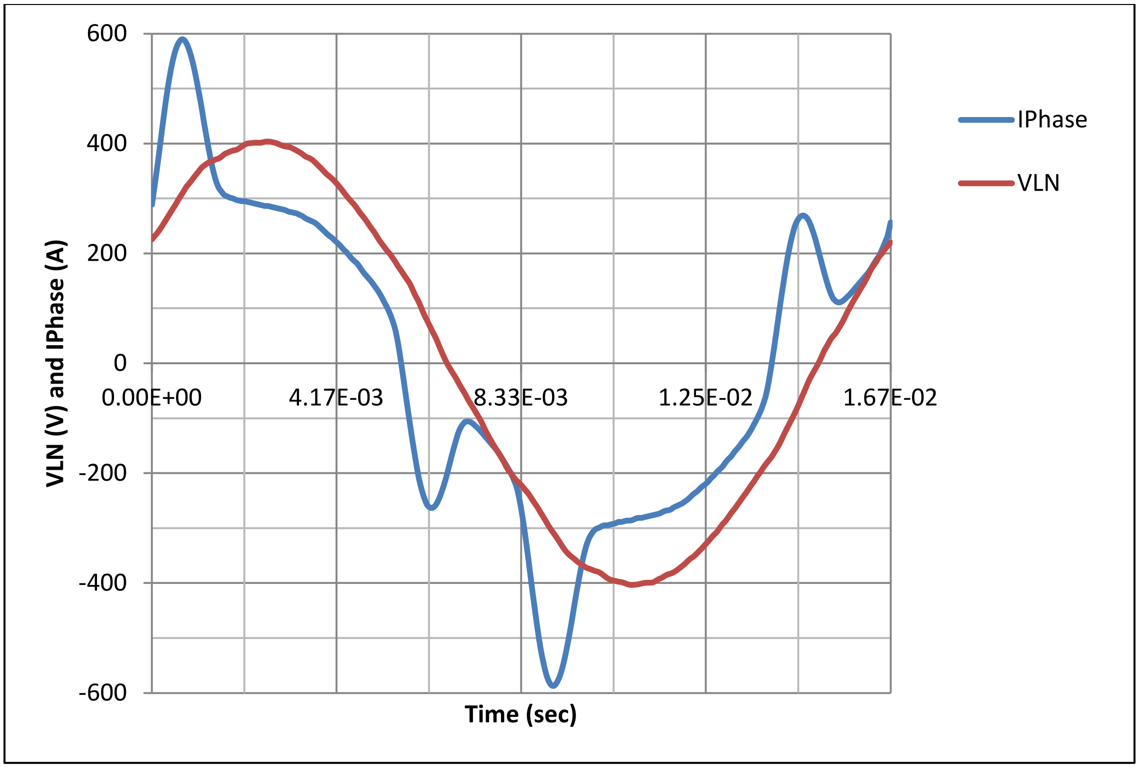


*Figure 1: Measured Line to Neutral voltage and Phase current from UV system*

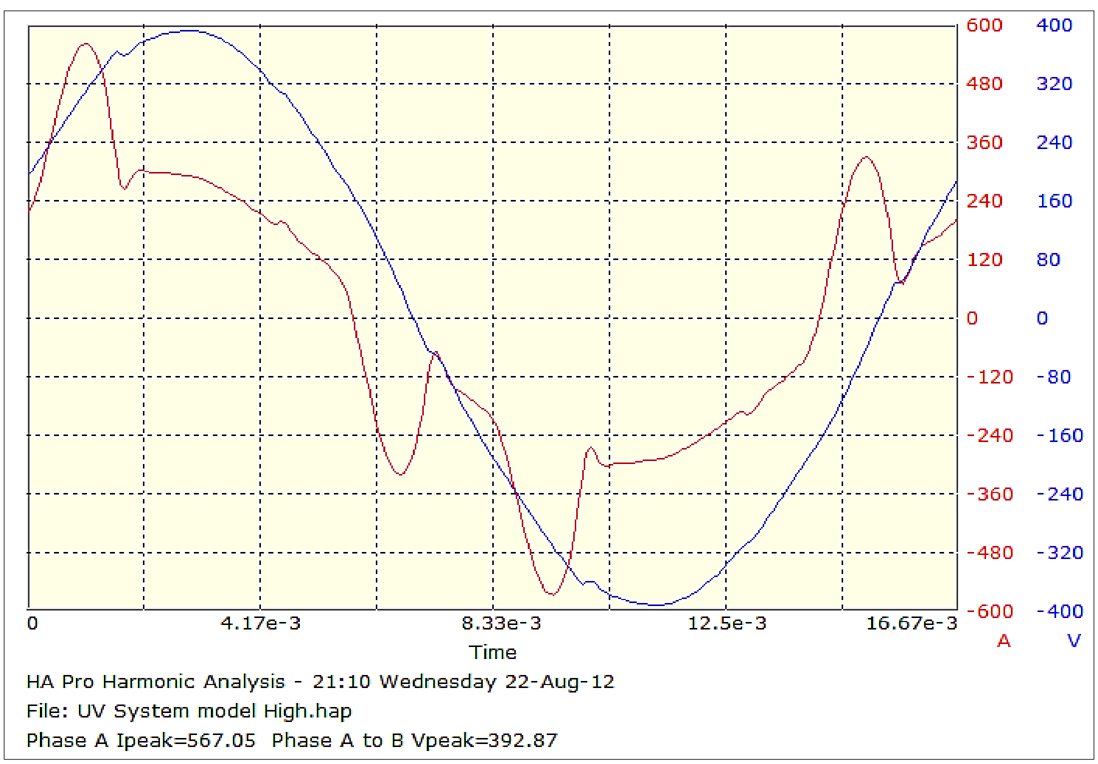


*Figure 2: Line to Neutral voltage and Phase current from HAPro model of UV system*

# Power quality improvement

From the analysis of the UV system, the total harmonic current produced is estimated to be about 100A. If power factor correction is needed, the required current is close to 170A. A 100A active filter was sized purely on harmonic current demand, installed and commissioned with the UV system. Using source and demand data in the plant, the IEEE 519 allowable TDD limit was calculated to be 12%. This set a clear goal for allowable harmonic current. The filter was tuned so that any remaining capacity was diverted to reduce the leading VARs produced by the UV system. This would make the UV system less susceptible to backup generator interaction. Using these guidelines, the filter was tuned so as to set a balance between harmonic correction and power factor correction. The measured results of the UV system operating with the filter are shown in Table 3. The THD is limited to 10% average for the three phases, while the power factor is improved to greater than 0.95 at full load. The leading vars generated by the system are limited to about 20% of its kVA rating.

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