APPLICATION NOTE

# Global vs Local Compensation using Active Filters

2018-05-21 – Revision 01

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## Abstract

This application note describes the benefits of global compensation over local compensation of harmonics in plants with numerous large variable speed drive, such as water treatment plants. By carefully applying global compensation instead of local compensation, a solution with a certain degree of redundancy is usually significantly more cost efficient. The results are general and does not only apply only to water treatment. It is also demonstrated that by carefully sizing a system, oversizing can be avoided.

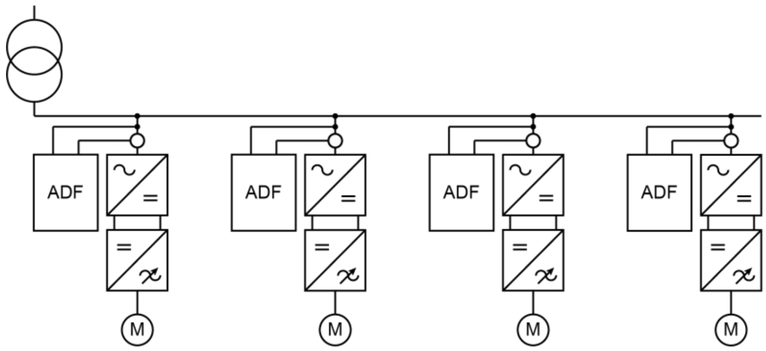

**KEYWORDS:** ACTIVE FILTERS, HARMONIC MITIGATION, LOCAL VS GLOBAL COMPENSATION, REDUNDANCY, WATER TREATMENT, IEEE519, IEC/EN61000-2-4, G5/4.

## Background

Consider following case, for a water treatment plant. The plant is comprised of four pumps, each 500 kW. In order to sustain normal operation, the worst case is using 3 pumps at 80 % load. Hence, the example facility has N+1 redundancy. Installed power is 2000 kW, maximum load during worst case conditions are 1200 kW or 60%.

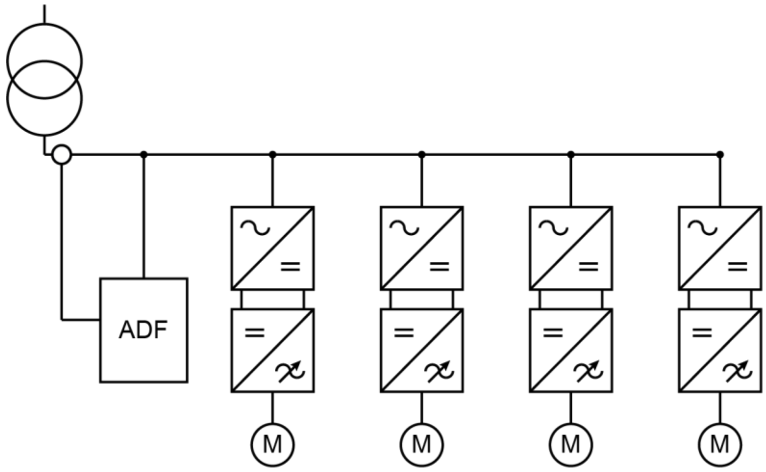
In order to mitigate the impact of harmonics, two options can be considered. The first option is to use low harmonic drives (LHD). Low harmonic drives can either be true low harmonics drives, i.e., a 6-pulse drive with a built-in active filter, or an Active Front End (AFE) drive which is only required if 4-quadrant operation is needed. For the sake of the cases given in this application note, we are considering true low harmonic drives. Since these types of drives (no matter LHD or AFE) must be sized for worst case conditions, every drive include all the needed compensation capability for each drive at full load.

First option is illustrated below, in case of an LHD using ADF technology. Each drive comprises its own, local compensation that can fully compensate the drive:




The second option is to use global compensation together with regular 6-pulse drives. In this case, the drives are connected like they would be when no compensation is added; in addition to this, a centralized active filter compensating the whole facility is used. In this case, the active filtering is sized to handle the worst case, which is 3 drives running at 80 % load. In this option, two scenarios are considered; meeting IEEE519-2014, usually interpreted for Low Harmonic Drives to be < 5 % THDI at all conditions, and meeting voltage harmonic requirements according to IEC/EN 61000-2-4 Class 2. This mandates less than 8 % THDV, and a falling spectrum of maximum individual harmonics ($V_5$ < 6 %, $V_7$ < 5 %, $V_{11}$ < 3.5 %, and so on).

Second option is illustrated below:




As indicated in the diagram above, the global compensation option is completely decoupled from the load, which increases flexibility during planning and installation. It also means the drives and filters can be installed, serviced and maintained independently of each other.

In all cases, the harmonic levels are obtained by using the ADF Online Sizing Tool, available for Comsys partners at [http://sizing.adfpowertuning.com](http://sizing.adfpowertuning.com).

For each case, three results are evaluated:

- Needed compensation in local (per drive) compensation
- Needed compensation on global compensation – without redundancy
- Needed compensation on global compensation – with redundancy for ADF (N+1)

**Example case 1: Meeting < 5 % THDI (IEEE519)**

First, we compare the amount of compensation needed to reach less than 5 % THDI. In this case, we consider the drives to be on a 2500 kVA transformer of 6 % impedance. Every drive is considered to have an equivalent AC Reactance of 2 %. The resulting needed compensation is stated both in Amperes (the needed harmonic compensation current; equals total nominal current from the active filter modules), and in number of active filter modules (type selected is PPM300v2B-3-A-120/480).

The table below summarizes the results for 5 % THDI requirements:

| | | | |
|---|---|---|---|
| **Drive** | 500 kW, LAC ~ 2 % | | |
| **Configuration** | 4x500 kW; 2.0 MW total non-linear load | | |
| **Grid** | 400 V; 2500 kVA @ 6 % | | |
| **Sizing premise** | Typical low harmonic drive specification<br>(THDI < 5 %, IEEE519-2014; SCR < 20) | | |
| **ADF Current THDI < 5 %** | > 351 ARMS | | |
| **ADF Modules** | ≥ 3 | | |
| **Worst case load** | 3 drives, 80 % load (corresponding to 60% total utilization) | | |
| **ADF Module** | PPM300v2B-3-A-120/480 (120 ARMS) | | |
| | | | |
| | **Local compensation** | **Global compensation (no ADF redundancy)** | **Global compensation (N+1 ADF redundancy)** |
| | | | |
| **Total ADF Current needed** | ≥ 1132 ARMS | ≥ 699 ARMS | ≥ 699 ARMS<br>(≥ 1049 ARMS incl redundant power) |
| **Total ADF Modules** | 12 | 6 | 7 – 9 |
| **Cost** | 100 % | 50 % | 58 – 75 % |

As can be seen, with local compensation, a total of 1132 $A_{RMS}$ is needed, which equates to 12 PPM300 modules. When global compensation is instead selected, the needed compensation current drops to about 699 $A_{RMS}$, which equates to 6 modules, or 50 % of the cost for compensation. In addition to this, if N+1 redundancy is required for the active filter compensation, 9 modules are needed if the compensation is grouped to three SCC2 controllers; if individual controllers are used, only 7 units are needed. Hence the cost is 58 – 75 % of local compensation.

It should be pointed out that the requirement of less than 5 % THDI is very stringent! Assuming no background distortion, even in global compensation where the amount of compensation is reduced, the voltage distortion is 5.79 % without compensation, dropping to 1.31 % when 6 ADF modules are running. Hence, applying the active filters in such a way yields a solution that in some sense is “too good!”. However, it must be noted that in some locations this type of result will still be a requirement (notably when IEEE519 and G5/4 is required) and in these cases, global compensation is still significantly much more economical than local compensation.

**Example case 2: Meeting IEC 61000-2-4 Class 2**

For the second case, IEC 61000-2-4 Class 2 was selected, as this is a requirement in many grids, and the requirement is mostly compatible with several requirements in marine classification societies such and DNV GL and ABS. In this case, we selected a slightly weaker grid, corresponding to a 1600 kVA transformer with 6 % impedance. In weaker grids such as marine applications, the result obtained will be somewhere between this case and the previous one. The source impedance is selected so that the results are relevant to many actual grids.

The same drives are chosen as in the previous case. Note that in this case the size of the local compensation (LHD or AFE) is still the same as before – these are always sized after worst case conditions, which means that a local compensation may be *vastly* oversized for any normal application!

The table below summarizes the results for 8 % THDV requirements:

| | | | |
|---|---|---|---|
| **Drive** | 500 kW, $L_{AC}$ ~ 2 % | | |
| **Configuration** | 4x500 kW; 2.0 MW total non-linear load | | |
| **Grid** | 400 V; 1600 kVA @ 8 % | | |
| **Sizing premise** | IEC 61000-2-4 Class 2<br>($V_{THD}$ < 8 %, falling spectrum on individual components) | | |
| **ADF Current THDI<5%** | > 351 $A_{RMS}$ | | |
| **ADF Modules** | ≥ 3 | | |
| **Worst case load** | 3 drives, 80 % load (corresponding to 60% total utilization) | | |
| **ADF Module** | PPM300v2B-3-A-120/480 (120 $A_{RMS}$) | | |
| | | | |
| | **Local compensation** | **Global compensation (no ADF redundancy)** | **Global compensation (N+1 ADF redundancy)** |
| | | | |
| **Total ADF Current needed** | ≥ 1132 $A_{RMS}$ | ≥ 194 $A_{RMS}$ | ≥ 194 $A_{RMS}$<br>(≥ 291 $A_{RMS}$ incl redundant power) |
| **Total ADF Modules** | 12 | 2 | 3 |
| **Cost** | 100 % | 16.67 % | 25 % |

As can be seen, the required number of modules in global compensation without redundancy drops from 6 to 2! The uncompensated voltage distortion (THDV) is 10.43 %, dropping to 7.77 % when adding the active filters. Moving on to N+1 redundancy, still only three modules are needed, now the THDV drops to about 6 %. In summary, the cost of compensation is about $1/6^{th}$ without redundancy, and $1/4^{th}$ using N+1 redundancy.

**Discussion and Summary**

As demonstrated previously, global compensation will often yield much more economical compensation. Normally, local compensation entails that each drive is fully compensated. In the examples above, the operating point is loading the drives to 80 %. If a lower operating point is selected, the difference in cost and harmonic filter size will increase, to the benefit of global compensation, as the local compensation is always designed to handle full load current.

One possibly surprising consequence is that when taking voltage distortion into account, 2N redundancy is more cost-effective in global compensation than N+1 redundancy using LHD or AFE!

For all the cases above, using local compensation sized for reaching THDI < 5 % according to IEEE519 would be sufficient to solve the problem with harmonic pollution. Also, in all the cases above, this solution constitutes overreaching. By considering the grid standard and the local requirements, and sizing the solution appropriately, a much more economically efficient solution can be obtained.

In addition to the above, since the amount of needed compensation is smaller in global compensation no matter compared to LHDs or AFEs, the total footprint and weight of the facility will be smaller.

Finally,

*Summary of conclusions:*

- Local compensation will in most cases require a bigger and more costly solution.
- Global compensation renders lower cost, and sometimes higher level of redundancy at a lower cost.
- In cases where requirements are mostly on the voltage, global compensation is a fraction of the cost of local compensation.
- Just applying IEEE519 will work, but investigating the appropriate solution using a sizing tool reduces cost and size significantly.
- Smaller physical size and weight using global compensation compared to local compensation.
- A decoupled harmonic mitigation protects the investment of the drives, as regular 6-pulse drives can be utilized, and filters and drives can be serviced and maintained independently.

**References**


[1.] IEEE Std 519-1992, *"IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems"*, IEEE, New York, 1993

[2.] IEEE Std 519-2014, *"IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems"*, IEEE, New York, 2014

[3.] IEC 61000-2-4 (2002), *"Environment – Compatibility levels in industrial plants for low-frequency conducted disturbances"*, IEC, Géneve, Switzerland, 2002

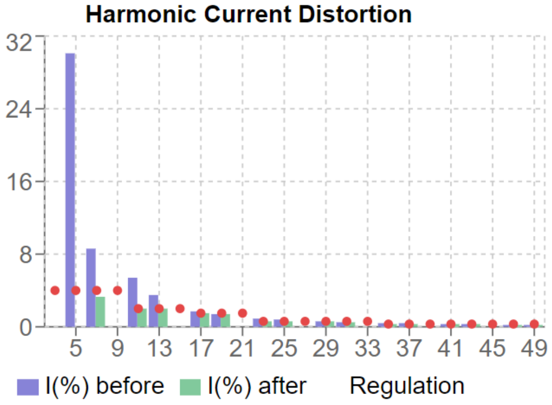
[4.] G5/4 (2001), *"Engineering Recommendation G5/4",* Electricity Association Services Limited, London, Great Britain, 2001

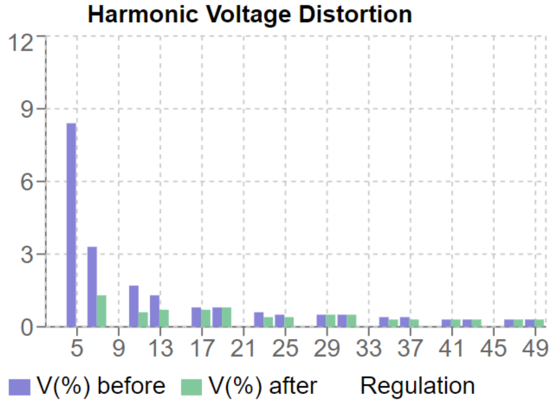
[5.] Managing Harmonics ($6^{th}$ ed. 2011), *"Managing Harmonics, A guide to ENA Engineering Recommendation G5/4",* $6^{th}$ Edition, Gambica, The Energy Networks Association, London, 2011

**Appendix A – Simulation Results**

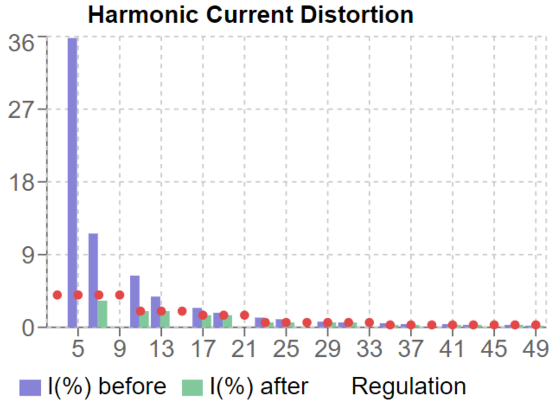
Below, bar graphs showing harmonic spectrums can be found for the cases discussed in the application note.

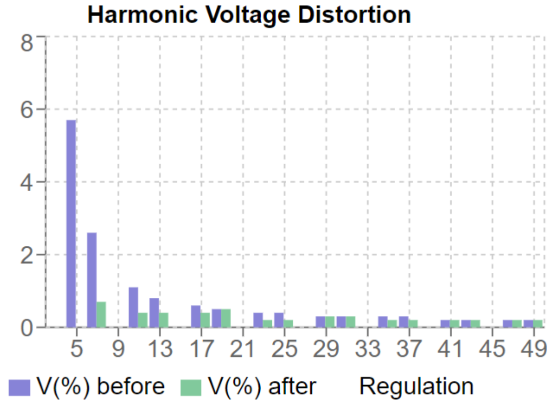
Below is local compensation, THDI < 5 %, 4 drives running at 100 %.




Below is global compensation, THDI < 5 %, 3 drives running at 80 %.




Below is local compensation, THDV < 8 %, three drives running at 80 %.