Comments on Feature "Power Factor Correction and Power Quality Issues" on page 42-46 in Jurutera May 2007

By: *Engr. Y.J. Cheng,* *Grad. IEM*

This feature on power factor correction and power quality issues is indeed an interesting article and timely for the public awareness on the seriousness of power quality issues. Engr. Mohamed Fuad has presented interesting facts on effect of harmonics toward power factor correction. However, this article has left out important and latest terminologies of power factor which was internationally recognised since the nineties, which is well documented in IEEE (Institute of Electrical and Electronics Engineers, Inc.) Standard 519-1992: "IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems" and ABS (American Bureau of Shipping) Article150 "Guidance notes on Control of harmonics in Electrical Power Systems". The 'Figure 2: A Power Triangle' shown in the article is only valid for electrical system with linear load. On contrary, when the electrical system consists of the linear and nonlinear loads, the power triangle (a 2-Dimensional view) has to be expended into a 3-Dimensional view as shown in the Figure A below due to the harmonic component from the nonlinear loads. The new component in the 3-D view is the distortion power (D), which is referring to the sum of power generated by the harmonic component in the electrical network. The other three components remain the same, *viz*. Apparent Power, Reactive Power, and Real Power. Figure A can be equated as:-

$$S(kVA) = V_{rms} I_{rms} = \sqrt{P^2 + Q^2 + D^2}$$

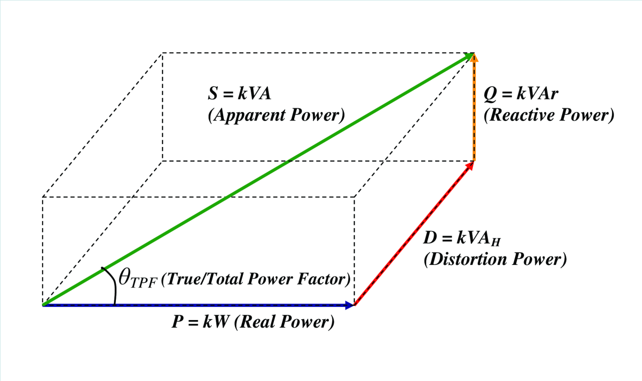

Figure A: Power Components in Electrical System with Harmonics

The power factor mentioned in the article is referring to the displacement power factor. Due to harmonics component in the electrical network, the power factor has been termed into three definitions, viz. True/Total Power Factor, Displacement Power Factor, and Distortion Power Factor, which are illustrated in Figures A-C respectively.

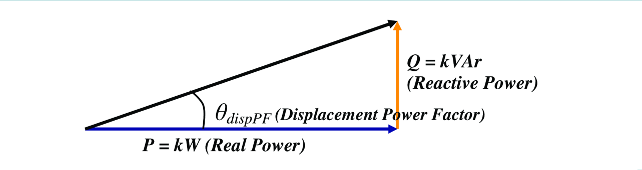

Figure B: Displacement Power Factor

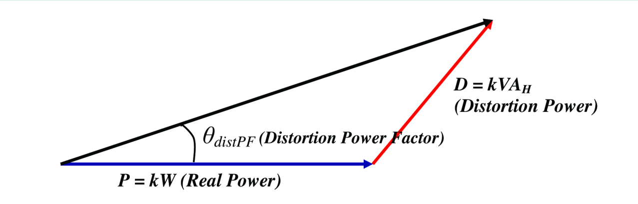

Figure C: Distortion Power Factor

Those power factors can be equated and defined as follows:

True/Total Power Factor : $\cos\theta_{TPF} = \cos\theta_{dispPF} \cdot \cos\theta_{dispPF}$

Displacement Power Factor (Fundamental Components):

$$\cos\theta_{dispPF} = \frac{kVAr}{kW}$$

Distortion Power Factor (Harmonic Components):

$$\cos\theta_{dispPF} = \frac{1}{\sqrt{1 + THD_v^2}} \; \frac{1}{\sqrt{1 + THD_i^2}}$$

where *THD = Total Harmonic Distortion*.

Hence, the statement in the article "*Many inverters are quoted as having a power factor of better than 0.95 when in reality, the true power factor is between 0.5 and 0.75*" is misinforming as it is referring to different type of power factor. The displacement power factor for inverters (a.k.a. variable speed drive (VSD) is usually closed to unity (0.9 to 0.95 lag). However, due to the harmonics current drawn by the inverter, the distortion power factor for inverters is much lower, as defined in the equation above. The total/true power factor is the combination of both displacement and distortion power factors. This can be apprehended, for example, if the *THDv* = 2%, *THDi* = 80%, the calculated distortion power factor is 0.78 lag. Assuming displacement power factor is 0.9 lag, then the true/total power factor is 0.7 lag. Hence, depending on which power factor that is referred to, each term will have different quantity and interpretation as well as solutions.

Usually, the common way to improve displacement power factor is by installing power factor correction, whereas the distortion power factor can be improved by reducing the harmonics distortion in current (*THDi*) and voltage (*THDv*). If the true power factor is low due to harmonics and assuming the displacement power factor is unity, by installing power factor correction will not help to improve the true power factor, but might cause voltage regulation issue due to over capacitive network. The solution for this case would be to install harmonic mitigation solution to further reduce *THDi* and *THDv* and hence make the distortion power factor closed to unity and eventually improve the true power factor. Therefore, knowing the right source of poor true power factor will help to implement the right solution.

In Section 10 of the article, the harmonic values mentioned the article is only partial. Practically, all the dominant harmonic order of the nonlinear loads should be avoided when designing and applying power factor correction. The dominant harmonic order for all type of nonlinear loads can be determined by using the following equation.

$h = np \pm 1$

where h = *dominant harmonic order*

n = *positive integer*

p = *number of pulse in the rectifier circuit of the nonlinear loads*

This can be comprehended as, for example, for a typical 6-pulse VSD, the dominant harmonic order is 5, 7, 11, 13, 17, 19,…*etc*, which is calculated based on $h = 6n \pm 1$. And for single-phase power supply which has 4-pulse rectifier, the dominant harmonic order is 3, 5, 7, 9, 11,…*etc*.

In addition, the cost of harmonic mitigation solutions is very subjective and relative in comparison, and also there are pros and cons of each solution. Albeit price is one of the factors in consideration, the effectiveness and consequences of each solution should be taken into consideration when applying harmonic mitigation solutions. Typically, passive filter is designed based on the load size, and mainly use as a localised solutions (closer to the loads). The structure of passive filter will act like a power factor correction when the load is not in operation, and hence will cause leading power factor when there is no load. This is one of the common practical issues with passive filter. On contrary, active harmonic filter is usually designed for global mitigation, which can compensate both harmonics and true power factor. This is made feasible with the advancement of power electronics technology. Notwithstanding, the price of one global solution compare to multiples of individual local solutions, might be relatively cheaper in some cases. Hence, the selection of harmonic mitigation solution should not be based on one factor, but the overall factors.

Besides, the power quality issues are not only limited to harmonics, but it covers wide range of voltage, current and frequency phenomena, which is well categorised in IEEE Standard 1159-1995. Albeit harmonic in electrical system is an interesting and complex issue, the misinterpretation of this topic will cause more undesirable consequences than improving the condition. Likewise, this feature is an interesting article, but certain topics in the article should be clearly defined and clarified in order to avoid confusion and misinterpretation. With this additional information, it is hope that the practicing engineers will be able to apprehend this topic sufficiently and create awareness about power quality issues. ■