A REVIEW OF HARMONIC ANALYSIS AND ITS MITIGATION TECHNIQUE IN INDUSTRIAL ENVIRONMENT USING 7% DETUNNED PASSIVE FILTER

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Abstract -With the advent of modern electronics, most of the industrial loads became nonlinear (E.g., Variable frequency drives, rectifier loads and UPS) in electrical systems. These loads are main sources of generating harmonics in the system. The presence of Harmonics in an industry will often result in malfunctioning of the electrical system. Harmonics is one of the major power quality issues in many processing industries like Cement industry, Marble industry, Steel Substations, Rolling mills, Printing mills, Quarries, Substationetc.,. Lower order harmonics cause major problems in most of these industries.
For harmonic reduction, there's a requirement to spot, measure the sort & level of harmonics during a system. Thus in review paper we evaluate the reactive power and Harmonic evaluation.

***Key Words*:**Harmonic reduction, Detuned Filter design, Substation.

1. INTRODUCTION

Highest power tariff is paid by Indian industry and the gap between supply and demand is expanding due to low power factor and lower quality of power resulting in loss of production and profits[1]. In order to reduce the kVA demand and to improve thepower quality of the system, maintaining high power factor was considered as the only necessary parameter in earlier days. Hence, more emphasis was placed on finding solutions to improve the power factor. But in the presence of harmonic-rich environment, mere PF improvement does not meet the challenge of improving the power quality. Hence, mitigation techniques of harmonics are of great importance in industrial electrical systems in order to increase system reliability, to reduce the losses in rotating machines, to avoid capacitor failures, and nuisance tripping of protection relays[2], [3]. Besides Load flow and stability studies, Reactive power flow studies, and power system studies should also contain harmonic analysis and the harmonic analysis studies for industrial systems [4], [5]. Here, harmonic analysis is done through power analyzer.

HARMONICS: Power quality has caused an excellent concern to electrical system engineers with the increasing usage of nonlinear loads like Static power converters, Rectifiers, Arc furnaces, Computers, telecommunication system, Television receivers, Saturated transformers etc.,[6]. These nonlinear loads end in generation of harmonics. High level of harmonic distortion is harmful to varied equipment within the installation and it also affects the utility also as Substation distribution systems.

The Total Harmonic Distortion (THD) may be a measure of the effective value of harmonic distortion.

$$THD(\%) = \frac{\sqrt{I_2^2+I_3^2+\dots\dots I_n^2}}{I_1} \times 100\%...(1)$$

Where THD is that the total harmonic distortion of the waveform differently is that the magnitude of the elemental component and are the magnitudes of the 2nd , 3rd, . . . and harmonic components.

As already stated, rectifiers constitute an outsized percentage of the nonlinear loads within the Substation- manufacturing industry. Thus, mere installation of capacitor banks within the harmonic-rich environment doesn't maintain the target power factor and doesn't improve the standard of power. that's why harmonic reduction techniques are required.

2. MITIGATION TECHNIQUES FOR REDUCTION OF HARMONIC DISTORTION:

Installation of harmonic filters would help within the reduction of harmonics. Generally, a harmonic filter comprises an inductor and a capacitor. Harmonic filters are mainly classified into Passive harmonic filters, Active harmonic filters [7], [8] and Hybrid harmonic filters. The passive harmonic filters prevent the undesirable harmonic current flow into the facility system by providing a high series impedance to dam

their flow, or a low-impedance parallel path is provided to divert the harmonic currents [9]. The passive filters are mainly utilized in supply networks to scale back the high level harmonic distortion, to enhance the facility factor by reactive power compensation at fundamental and to avoid the overloading of the capacitors. The active harmonic filters are the perfect solution for installations which are having an outsized number of single-phase and three-phase loads generating harmonics like Computers, UPC, Lifting equipment. These also are used for elimination/reduction of problems like voltage sags and flickers occurring within the distribution networks. The third sort of filter is hybrid filter and it's composed of both active and passive filter. during this work, detuned passive harmonic filter is meant and is taken into account as a mitigation technique for harmonic reduction.

3. DESIGN OF A DETUNED HARMONIC FILTER:

A detuned harmonic filter consists of an influence capacitor and a tuning reactor. it'll act in parallel with the fixed capacitor banks. For design purpose, data regarding load details, existing power factor, targeted new power factor, voltage and current total harmonic distortion etc., should be collected and this data is obtained from an influence analyzer.

At The harmonic filter design are often wiped out the subsequent steps:

STEP-A: Fourier analysis is completed at Amara Raja IBD MVRLA division at transformer-1 of rating 2000 kVA and electrical data like total load, average monthly power PF, maximum load current, voltage and current total harmonic distortions are obtained from power analyzer. These details are given in Table 1 and it's as follows:

Table 1: Electrical Data of Substation

S. N0.	Parameters	Value
1 f_R	Total load(kW)	414
2	Average monthly PF	0.773
3	Maximum load current	60 A
4	V_{THD}	6.9%

STEP-B: Assuming the targeted power factor to be 1.0, calculate the specified total kVAr to boost the facility factor from 0.773 to 1.0.

kVAr required = kW * (tan) . . . (2)

Existing PF = 0.773 ∴ $\tan\theta_1$ = 0.821,
Target PF = 1.0 ∴ $\tan\theta_1$ = 0,
kVAr required = 414.32 * 0.821 = 340.04 kVAr≅ 350 kVAr.

Out of 350 kVAr calculated from Eqn. (2), we employ 10% kVAr for no load loss of transformer, 20% kVAr for base load and remaining kVAr for PF correction.
Filter kVAr = 70% of 350 kVAr = 245 kVAr

But generally standard ratings of the capacitors available within the market are within the ranges of 12.5, 25, 50 and 100 kVAr respectively. So, we consider 250 kVAr because the filter kVAr.

STEP-C Design of filter: A detuned filter consists of three capacitors connected in delta and three reactors connected thereto serial . we'd like to calculate the tuning factor%, reactor and capacitor values in mH/phase and µF/phase and also their kVAr values respectively.

Step-1 Calculation of Tuning factor %: so as to scale back the harmonic contents and to avoid resonance, the reactors used must be some percentage of capacitors used i.e., 'Tuning Factor'.

Percentage tuning factor is defined as,

$$P=\frac{\text{Reactor reactance at system frequency}}{\text{Capacitor reactance at system frequency}} \times 100\ \% . . . (3)$$

Substituting reactor reactance i.e. 2.Π. .L and Capacitor reactance i.e. at the system frequency Eqn. (3) can be written as,

$$\frac{P}{100} = 4.\pi^2.\ L.\ C.\ f_g^{\,2}. . . .(4)$$

The resonance frequency is given as,

$$f_R^{\,2} = 1/4.\pi^2.L.C. . . . . .(5)$$

Using Eqns. (4) & (5), tuning factor "p" is given as,

$$f_R = f_S/\sqrt{(\frac{P}{100})}. . .(6)$$

The following criteria should be considered for matching of the reactors and capacitors to get optimum performance from a detuned filter:

- The resonance frequency is taken into account consistent with the foremost lower order predominant harmonics within the system.
- The capacitor voltage across the terminals will increase thanks to inductive reaction of the reactor. So, capacitors must be chosen 10% above its actual rated voltage.
- Thanks to the presence of upper voltage rated capacitors and reactors during a harmonic filter, rated reactive power isn't obtained. So, the obtained power must be calculated so as to avoid low compensation.

Step-2 Analysis of Detuned filter: For analysis purpose allow us to consider the particular connection of detuned filter and it's as shown in Fig. 1.

In Fig. 1, Star equivalent connection and single line diagram are also represented. X_L
Analysis of Detuned Filter are often done by using its single line diagram representation as X_{CY} shown in Fig. 1.

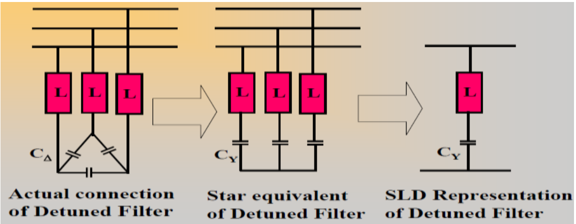

Fig. 1- Representation of detuned filters in star connection &Single line diagram

Let internet are available kVArat Bus = N_C

Let the System Line Voltage in Volt = V

Let Line current of the Filter inAmpere = I_L

Let the Tuning thing about in% = p
Let the Inductive Reactance inOhm= X_LLet the Capacitive Reactance inOhm= X_CLet the Capacitor Rated Voltage in Volt= V_C

From Equation (3), the Inductive Reactance are often written as:

X_L=p%full of $X_c = \frac{p}{100} \times X_c$. . .(7)

Line current of the Filter is given by,

$I_L = \frac{V}{\sqrt{3}} / (X_C - X_L)$

Substituting the worth of within the above Equation are often written as,

$I_L = \frac{V}{\sqrt{3}} / X_C (1 - \frac{p}{100})$. . .(8)

The 3 phase kVAr, at Bus is given by,

$N_c = \sqrt{3}.V.I_L/1000$

Substituting the worth of in the above equation are often written as,

$N_c = V^2/1000 . X_C (1 - \frac{p}{100})$ . . . (9)

2.1) Calculation of Capacitive Reactance: From Eqn. (9), the star equivalent Capacitive Reactance is obtained as,

$X_{CY} = V^2/1000 . N_C (1 - \frac{p}{100})$ . . . (10)

2.2) Calculation of Inductive Reactance: From Eqn. (7), the Inductive Reactance is given by,

$= \frac{p}{100} \times$

Substituting the worth of within the above equation are often written as,

$X_L = V^2/1000 . N_C (\frac{100}{p} - 1)$ . . . (11)

2.3) Calculation of Capacitance per Phase: The Capacitive Reactance is additionally given by,

$X_{CY} = 1/2.\pi.f.C_Y$ . . . . (12)

From Equations (12) & (10), we obtain

$\frac{1}{2}.\pi.$ f. $C_Y = \frac{V^2}{1000}.N_c.(1-\frac{1}{100})$

Fromthe above equation, capacitance per phase are often obtained as,

C_Y=1000 .$N_C (1 - \frac{p}{100}) / V^2.2.\pi.f$ in Farad . . .(13)

Capacitance per introduce μF is given by,

$C_Y = 10^9 . N_C (1 - \frac{p}{100}) / V^2 . 2.\pi.f$ . . . . .(14)

2.4)Calculation of Inductance per Phase: The Inductive Reactance is additionally given by,

X_L= 2. π.f.L . . . .(15)

From Equation (7), the Inductive Reactance is given by,

$X_L = \frac{P}{100} \times X_{CY}$

Substituting the equations (15) & (12) within the above equation,

2. π. f. L= $\frac{p}{100} \times \frac{1}{2.\pi.f.C_Y}$

Fromthe above equation, Inductance per Phase are often obtained as,

L = $\frac{p}{100} \times \frac{1}{4.\pi^2.f^2.C_Y}$ in Henry . . . . . . (16)

2.5) Calculation to Estimate the Rated Voltage of the Filter Capacitor: Consider Fig. 2 for the calculation of rated voltage of the capacitor. V_C

Fig. 2- Single Line Diagram of detuned filter

From Fig. 1, Line current I is given by,

$$I = V/X_{eq} = V/X_C\,(1 - \frac{p}{100})\ldots.(17)$$

Voltage across the capacitor is given by,

$V_C = I.\,X_C$

Substituting the worth of I within the above equation are often written as,
$V_C = V/\,(1 - \frac{p}{100})$

Allowing 10% for over voltage, the rated voltage of the capacitor is given by,

$$V_C = 1.1\,V/\,(1 - \frac{p}{100}) \qquad \ldots\ldots(18)$$

2.6) Calculation of kVAr of the Capacitor: The kVAr of the capacitor at its rated voltage V_C is given by,

$$\text{kVAr of capacitor} = V_C^{\,2}/\,X_{CY}\;.1000\ldots.(19)$$

Substituting within the above equation, we obtain

$$\textbf{kVAr of the capacitor} = (\frac{V_C}{V})^2 \times N_C \times (1 - \frac{p}{100}) \quad \ldots(20)$$

During measurements we found that 5th order and better order harmonics were beyond their limits as per IEEE Standards 519[10]. So, we opted to style detuned filters with tuning factor as 7%. The 7% detuned filters

3. HARMONIC MEASUREMENT:

The following observations are made:
(1). Input line current is reduced from 68 A to 62 A.

6. CONCLUSIONS:

Thiswork presents a review design and results of seven detuned passive harmonic filters (reactors) within the Substation. The installation of detuned filters under harmonic conditions shows reduction of harmonics within the Substation

REFERENCES:

[1] Ashish Pandey, Kothari D.P. and Bhatt S.S., “Power Quality Issues and Power Electronics” International Journal Energy Technology and Policy, Vol. 4, pp 4-18, 2006.

[2] Walter T.J. Hulshorst, Keet L. and John Enslin E.R., “Harmonic Analysis and Mitigation in Large Industrial Steel Substations” electric power Quality and Utilization Magazine, Vol. 11, pp 57-63, 2006.

[3] M. Z. El-Sadek, power grid harmonics, 2nd edition, Mukhtar Press, Egypt, 2007.

[4] IEEE Std 399-1997, Recommended practice for industrial and commercial power analysis , ANSI/IEEE, 1997.

[5] Khatavkar V.V., Chapbekar S.N., “Study of Harmonics in Industries - Power Quality Aspect”, Electrical India Magzines, Vol. 46, pp 188-192, 2006.

[6] Elham B. Makram, Kasikci, “Harmonics and Quality of Power” Proceedings of Ninth International Conference, IEEE, Vol.3, pp 810 - 815, 2000.

[7] António P. Martins, “The Use of a lively Power Filter for Harmonic Elimination and Power Quality Improvement during a Nonlinear Electrical Installation”. IEEE Transactions on Industrial Electronics, pp 1-5, 2000.

[8] Escobar, G., Stankovic, Cardenas A.M., Mattavelli V.P., “An Adaptive Controller for a Series Active Filter to Compensate Voltage Sags, Unbalance and Harmonic Distortion”, Proceedings of VIII IEEE Technical Proceedings, pp. 275 - 280, 20-24, 2002.

[9] B. Singh, B. N. Singh, A. Chandra, K. Al-Haddad, A. Pandey, and D. P. Kothari, “A review of three-phase improved power quality AC-DC converters,” IEEE Transactions on Industrial Electronics, vol. 51, no. 3, pp. 641–660, 2004.

[10] IEEE Std 519, recommended practice and requirements for harmonics control in electric power systems, ANSI/ IEEE, 1992.