Design of Different Aspects of Capacitor of Single Tuned Shunt Passive Harmonic Filter of Industrial Distribution System

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Abstract – Capacitors are effectively used in industrial power systems for power factor correction. This capacitor is used in harmonic filter, to minimize the total harmonic distortion of the power system. This paper presents the design aspects of the power filter capacitor related to its loading indices and limits in the industrial distribution system. The three phase power system and single tuned passive filter is designed, modeled and simulated in MATLAB by using the actual data collected from industry is used.

Index Terms – Power system, Harmonic distortion, Passive filter, Industrial distribution system.

Introduction

With the large use of nonlinear power electronics devices, harmonic distortion in the power system caused by these nonlinear loads is increasing. Harmonics decreases the quality of power system. These harmonics cause faulty operation and overheating of equipment in the power system. Other problems consist transformer overloading and heating, meter errors and power cable faults. To overcome such faults and problems, harmonic mitigation is more important for both service providers and consumers. Therefore, it becomes necessary to decrease the harmonics in power system. The power quality issues are led to implementation of standards and guidelines such as IEEE-519 for controlling harmonics on the distribution power system along with the recommended limits. The 5% voltage distortion limit was recommended below 69 kV while the limit on the current distortion is fixed in the range of 2.5% to 20% depending upon the size of the customer and the system voltage.

Passive power filters and active power filters are commonly used to suppress the harmonics. PPFs are the necessary part used to realize reactive power compensation because of simple structure and low cost. APFs are used to improve harmonics suppression effect due to high cost and large capacity. So design of PPF is an important issue which influences the general performance of passive power filters. The goal of design is to achieve a group of PPF's parameters which have better harmonics suppression effect, higher capacity of reactive power compensation and lower cost.

Many research have been carried out on power harmonic mitigation using different types of filters. The problem of power harmonics in power distribution systems has been studied by using passive power filters. The MATLAB modeling and simulation of single tuned Passive filter has been studied. This paper shows the different design aspects of capacitor for single tuned shunt passive filter on harmonics of industrial distribution system.

Objective:

The main objective of this paper is to study different design aspects of capacitor for single tuned shunt passive filter on harmonics of industrial distribution system.

Power System Data:

The power system data is collected for the industry C'Cure Building Products. Three-phase system and single tuned power filter is designed and modeled in Matlab. Power system parameters and system harmonic data of this modeled system is considered in the simulation.

The designed single tuned passive filters parameters are shown in following table

Parameters	Phase 1		Phase 2		Phase 3	
	5^{th}	7^{th}	5^{th}	7^{th}	5^{th}	7^{th}
Qc(kVA)	8	8	10	10	9	9
Xc(ohm)	8.3786	8.3786	6.6822	6.6822	7.2136	7.2136
C(uF)	379.91	379.91	476.35	476.35	441.25	441.25
Xl(ohm)	0.3351	0.1709	0.2672	0.1363	0.2885	0.1472
L(mH)	1.0668	0.5443	0.85	0.434	0.918	0.4686
R(ohm)	0.04117	0.0294	0.0328	0.0234	0.0354	0.0253
Q	40.7	40.7	40.7	40.7	40.7	40.7

Table 1: Filter Parameters

Harmonic Filter Capacitor:

The capacitor should be designed so that operation during normal conditions should not

result in voltages or reactive power that exceeds 100% of the filter capacitor unit nameplate rating. IEEE Std. 1036-1992 gives continuous operation limits in excess of 100% nameplate rating. However, these limits are overload capacities and should be reversed for contingency operation only.

For single tuned passive filter the capacitors kVAr rating is selected such that it can perform following functions.

1) Power factor improvement

2) Specific harmonic reduction

For designed filter the capacitor ratings are considered to improve the power factor to 0.99. There maximum rms current rating, capacitance value and kVAr ratings are given in following table Table 2.

Parameters	Phase 1		Phase 2		Phase 3	
	5th	7th	5th	7th	5th	7th
Irms(max)	35.21	35.96	41.82	45.10	38.10	42.64
C(uF)	379.91	379.91	476.35	476.35	441.25	441.25
kVAr rating	10.14	10.10	11.69	12.66	10.49	11.91

Table 2: Filter Capacitor Specifications

Capacitor Loading Indices and Limits:

The allowable overload limits of capacitors based on standards are shown in Table 3.

kVAr	135%
RMS Voltage	110%
sum of peak voltages	120%
RMS current	180%

Table 3: Standard Capacitor Loading Indices and Limits

All of these parameters should be checked when applying capacitors in a harmonic environment, especially if the capacitors are parts of a filter.

For phase 1, 5th tuned capacitor following values are obtained.

Duty	IEEE limit	Rated value	Obtained values	Obtained limit
kVAr	135%	8000	10146	126.82%
RMS Voltage	110%	258.9	260.54	100.63%
Sum of peak voltages	120%	263.1	288.09	109.49%
RMS current	180%	30.89	35.2195	113.98%

Table 4: Capacitor Loading Limits for 5th Tuned Capacitor

All the obtained values are not exceeding the IEEE limit. Remaining phases capacitors are also not exceeding the IEEE limit. Similarly for other capacitors also obtained values are within IEEE limit.

Capacitance Tolerance:

The following capacitor parameters must be defined when designing a filter to achieve a specified tuning point

1) Capacitance variation with temperature

2) Capacitance manufacturing tolerance

The effect of the capacitance tolerance on the performance of the harmonic filter must be evaluated. Capacitor units built according to IEEE std. 18-2002 since 2002 have a manufacturing tolerance ranging from 0-10% at 25 degree centigrade internal temperature.

In harmonic filter design, the capacitor manufacturer must select a tolerance for individual units so that the filter capacitor bank capacitance tolerance is met. The capacitance tolerance of individual units should not exceed _5% of the rated unit capacitance.

Capacitance variation over the operating temperature range may be significant. Capacitor manufacturers can usually provide the variation of capacitance with temperature.

Conclusion

In order to reduce the harmonics in the industrial distribution system, this paper has presented the different design aspects of capacitor of the passive power filter which is also used for power factor correction. The result obtained are within the IEEE limit.

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