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Design of air core reactor of single tuned shunt passive harmonic power filter used in industrial distribution system

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Abstract
Shunt passive harmonic filters are effectively used to minimize voltage distortion in industrial power distribution systems. Different methods of filter design are considered for different filter configurations. Capacitors and reactors are effectively used in passive harmonic power filter. This paper presents the design of air core reactor of single tuned shunt passive harmonic filter of industrial distribution system. The three phase industrial power system and single tuned passive power filter is designed and it is modeled, simulated in MATLAB using the actual industrial data which is collected from the industry is used.

Keywords: Shunt passive harmonic filter, voltage distortion, MATLAB, Industrial power distribution system.

Introduction
Now a days, the extensive use of modern power electronic equipment in industrial distribution systems causes some adverse effects like high voltage distortion, transformer overloading, power cable faults, faulty operation of relays and circuit breakers, low power factor in low voltage customers [1-4]. Therefore, it is necessary to decrease these harmonics in power distribution systems. To mitigate these harmonic problems in industries distribution systems, the shunt passive filters are used. Passive power filters are cost effective among all mitigation techniques of medium and high-voltage systems. They supply reactive power to system and highly effective in reducing the harmonic components. Basically, filter banks are installed in the medium-voltage systems are able to provide reduction in voltages and currents harmonic distortions after their design and planning. The other solution is use of active filters [5]. These devices are operate by rectifying waveform and storing the energy in the direct current side; then, inverter transforms this energy to alternating current side to reconstruct waveform at desirable magnitude and angle. Active power filters operate well in low voltage distribution systems, but their complexity and cost when operating at medium, high-voltage systems is more. Therefore, passive filters are the most suitable mitigating devices.
The power harmonic problems are led to implementation of the standards and guidelines such as IEEE-519 for reducing the harmonics on the distribution system along the recommended limits. The 5% voltage harmonic distortion limit was recommended for below 69 kV and the limit for the current harmonic distortion is in range of 2.5% to 20% depending upon size of the customer as well as the system voltage [6-8].
The problem of power harmonics in power distribution systems has been studied by using passive power harmonic filters. The MATLAB modeling, simulation of single tuned Passive power filter has been studied. This paper discusses the design of air core reactor of single tuned shunt passive harmonic filter of industrial distribution system.

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

Power System Data
The industrial power distribution system data is collected from the industry C'Cure Building Products. Three-phase power system and single tuned harmonic power filter is designed and modeled in MATLAB. Industrial power system parameters, system harmonics and its other data of this modeled power system is considered in MATLAB simulation.

The designed single tuned passive filters parameters are shown in following table no. 1

Table 1: Power Filter Parameters

Parameters	Phase 1		Phase 2		Phase 3	
	5^{th}	7^{th}	5^{th}	7^{th}	5^{th}	7^{th}
Qc(kVAr)	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

Harmonic Filter Reactor
Filter reactors are of three types,
1. **Dry type, air core reactors:** used in medium and high voltage applications.
2. **Dry type, iron core reactors:** used in low and medium voltage applications.
3. **Fluid filled, iron core reactors:** used in medium voltage applications.

The reactor should be rated to withstand at a short circuit at the point between reactor
and the capacitor [9]. The insulation (BIL) of reactor should be similar to that of the power transformers connected at that same voltage level. Parameters to include when specifying a reactor are
- 50-Hz current,
- Harmonic current spectrum,
- Short-circuit current,
- System voltage,
- System BIL (Basic Impulse Level).

Three phase iron core harmonic power filter reactor should be avoided in situations where performance of the filter network is critical. It is very difficult to adjust inductance of one
phase without affecting inductance of other two phases.
The advantages of an air core coil are as follows:
1. The coil inductance is independent of current, because there is no ferromagnetic core to saturate by current increasing.
2. There is no iron loss which affect the ferromagnetic cores, then you will get the better Q Factor and lower harmonic distortion as the frequency is increased
3. They can be used to operate at frequencies as high as 1 GHz

Design of Air Core Inductor
An air core coil is an inductor formed by winding the several turns of enameled wire on a none-ferromagnetic cylinder that cylinder can be removed after construction the coil [10].

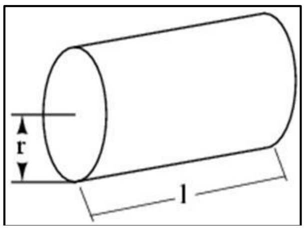

Fig 1: Construction of the Filter Reactor Coil

$$L = \frac{N^2 \mu A}{l}$$

$$\mu = \mu_0 \mu_r$$

where, L= Inductance of coil in Henrys.
N = no. of turns
μ = permeability of core material
μ_r = Relative permeability (μ_r =1 for air)
μ_0 = 1:26 *10^{-6} T-m/At Permeability of free space
A = Area of coil in square meters = πr^2
l = Average length of coil in meters.
Considering l =25 cm and r =6.5cm, From standard wire gauge chart,
- SWG = 4
- Diameter = 5.18922 mm
- Resistance = 0.81508 ohm/km
- Maximum current = 60 amp

The number of turns, length of wire and number of layers calculated and shown in following table.

Table 2: Filter Inductor Specifications

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
L(mH)	1.0668	0.5443	0.85	0.434	0.918	0.4686
N	126	90	113	81	117	84
No. of Layers	3	2	3	2	3	2

Conclusion
In order to reduce the harmonics in the industrial distribution system, this paper has presented the design of design of reactor for single tuned shunt passive filter on harmonics of industrial distribution system. The results obtained are within the IEEE limit.

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