# MAGNETICALLY CONTROLLED REACTOR FOR HARMONIC ELIMINATION

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**Abstract- Power electronics has revolutionized the electrical industry but it comes with certain drawbacks. Harmonic is one of the issues with the power electronic system which needs to be addressed. Currently, a passive filter is being used to eliminate these problems. N-numbers of tuned filters are required to eliminate various harmonics. Effective use of filter can be done by the use of special purpose of reactor known as Magnetically Controlled Reactor (MCR). This paper presents a new filtering scheme with the use of MCR which works on the principle of DC biasing. Proper controlled excitation is given to the DC bias to have control on the reactance value. This paper also explains more about the control algorithm, the filter performance analysis through simulation results.**

**Keywords:** ***Harmonics, Passive Filter, Variable Permeability, Magnetically Controlled Reactor.***

## I. INTRODUCTION

Power Quality is the ability of electrical network to maintain pure and steady power supply. In other words, Power Quality is always the availability of pure sinusoidal wave [1]. This wave is within standard limit of voltage and frequency but no real power source is ideal & generally can deviate in following ways, Voltage variation, Frequency variation, Waveform distortion. The oscillation of voltage & current follows the form of sinusoidal nature. However, it can alter due to imperfection in loads/generator. This imperfection referred to the distortion of the ideal waveform is knows as total harmonic distortion.

In order to prevent harmonic from affecting the supply system, IEEE 519 has been established as the recommended practices & requirements for harmonic control in the electrical power system [2]. So in order to meet this IEEE std 519 many power Quality improving methods have been proposed e.g. use of linear elements (in passive filters) having various contribution such as RL,LC,LLC etc Non-linear elements active filters having DC link. Passive filters are widely used as they don't require any external power supply, Can handle large current & high voltage, can handle large power supply, is very re liable & hence is more used comparative to active filters [3, 4]. But there is need of separate filter for each harmonic this disadvantage of passive filter makes harmonic filtering costly and bulky. In this proposed work the above disadvantage is eliminated by the use of Magnetically Controlled Reactor (MCR) [5, 6].

Generally industrial loads have a peculiar demand according to the operation being done. As in steel industry according to the arcing in the arc furnace the power supply changes i.e. harmonic content in various stages changes and hence there is need of all the harmonic filters at all time of operations. This need of all filter can be eliminated by selective elimination of harmonic in a particular stage of operation of the arc furnace by using MCR & switched capacitor dominant harmonic can be eliminated at any time with only one filter scheme [7]. The Controllable reactor is based on the magnetic amplifier, using a dc control circuit to change the saturation degree of the iron core [8, 9]. Magnetically controlled shunt reactors are currently being employed in various extra high voltage (EHV) and ultra-high voltage (UHV) applications as reactive power compensation, to improve systems dynamic performance and damping power system oscillation as well as fault current limiting reactor [5-10]. MCR's are yet to be utilized to their full extend for medium voltage (MV) and low voltage (LV) application. This work will contribute in improving MCR potential in MV and LV system.

## II. PROPOSED SCHEME

Current flows through the least impedance path. Passive filters provide least impedance path to harmonic currents by tuning the filters at particular frequency [3]. Value of Inductor and Capacitor is so selected that it resonates at a particular tuned frequency which in turn provide the required low impedance path to the harmonic current.

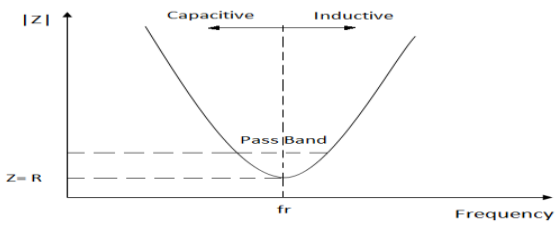



Fig.1. Single Tuned harmonic filter |Z| vs Freq

According to Fig.1. at resonance frequrncy (fr) the filter circuit is resistive, the impedance minimum with value Z=R and power factor unity. R << Xl (at fundamental frequency). In order to provide least impedance path shunt connected passive filters are used. Dynamic non-linear loads produced different order of harmonics at different time instant. For eliminating this, numbers of tuned filters are required [4]. MCR is a variable inductor which can be used with specific value of capacitor to tune for the present dominant harmonic and reactive power support in the system by the help of control circuit and thyristor switches for selecting appropriate capacitors at different time instant as shown in Fig.2. [11].

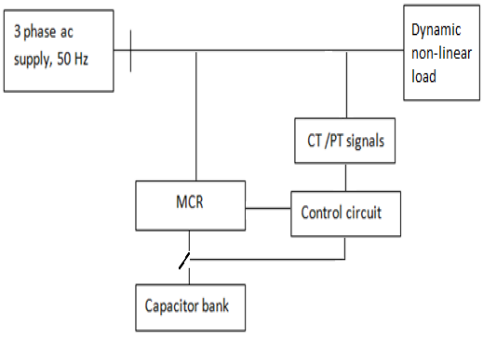
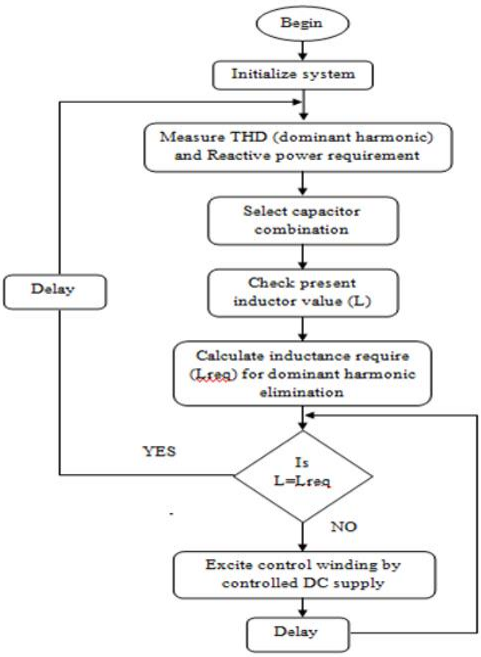



Fig.2. Block diagram of proposed scheme

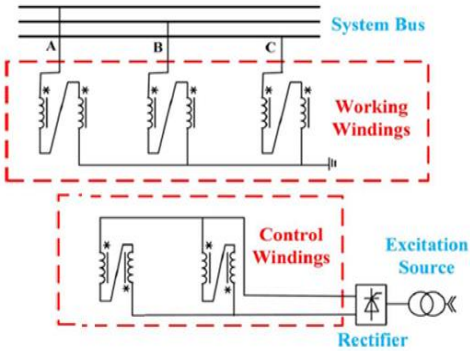
The flowchart explains detailed overview of MCR tuned filter where THD and reactive power measurement is done, capacitor and inductor value are calculated according to dominant harmonic present. Inductor value is checked and required value is obtained by changing excitation level of control winding [12].




Flow chart 1. Sequence of operation

## III. OPERATING PRINCIPLE

The working principle of MCR is based on magnetic flux phenomenon. MCR circuit is divided into two parts that is working winding and control winding which is shown in FIG.3. [13, 14] MCR works according to the control of magnetic saturation phenomenon as a magnetic magnifier




[11].

Fig.3. structure of MCR winding

The Sequence of operation is as follows
When control winding is excited with controlled dc current which produces magneto-motive force given by

$$\frac{dB_{ac}}{dt} = \frac{V_m \sin(\omega t + \phi_m)}{A_b N} \qquad (1)$$

$$F_m = I_{dc} * N \qquad (2)$$

The magneto-motive force produces magnetic field

$$H = F_m / l_e \qquad (3)$$

The field produces flux density

$$B = \mu * H \qquad (4)$$

At saturation of magnetic core even if Magnetic flux intensity (H) increases ΔB is very small hence to satisfy the equation (4) $\mu$ changes accordingly represented by Fig 4.[12].

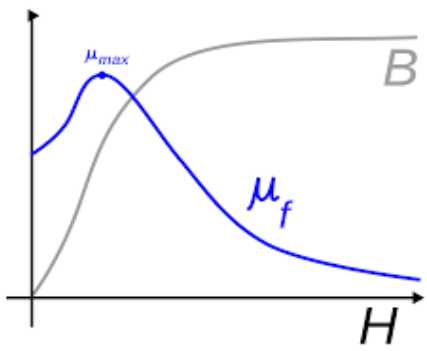



Fig.4. B Vs H & $\mu$ Vs H curve

Where,
B= magnetic flux density in Tesla

H= magnetic flux intensity in Ampere-Turn/Meter

$\mu = \mu_0 \mu_m$

$\mu_0$ is permeability of air and $\mu_m$ is permeability of magnetic material

As controlling $\mu$ will control the value of inductor because L is directly proportional to $\mu$.

The equation (5) for iron core inductor is given by

$$L = \frac{4\pi\mu A N^2}{MPL} \qquad (5)$$

Where,
L=value of inductance in Henrys

N= Number of turns

A= cross-sectional area of coil in sq-meter

MPL = magnetic path length in meters

## IV. SIMULATION RESULT

Simulation carried out by the use of variable load which produces different order of harmonics at different time instance are effectively eliminated with the use of magnetically controlled reactor in L-C combination of passive filtering [15, 16].

Because of the varying order of harmonic load 5th and 7th harmonics are present in 0.0sec to 0.5sec and 11th and 13th order of harmonic presents in 0.5sec to 0.8sec of period which is illustrated in Fig.5

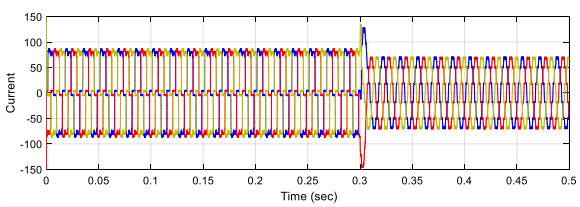
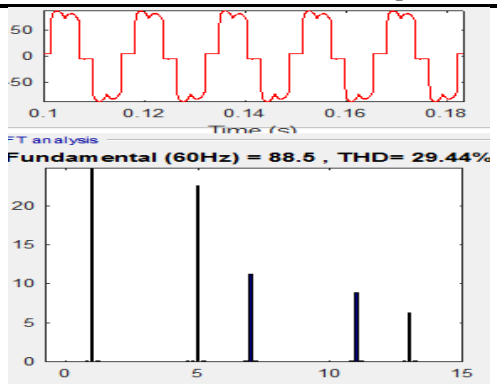
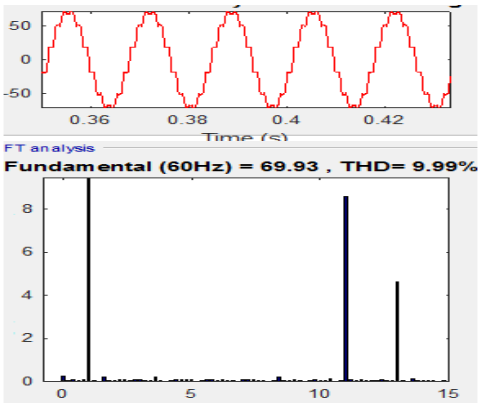



Fig.5. waveform of phase A of load current (without MCR)

. FFT analysis is carried out on varying harmonic load current. Total harmonic distortion of particular harmonics is also shown in Fig.6. THD of 5th and 7th harmonics are 16.40% which is beyond the IEEE standard and THD of 11th and 13th harmonics are also beyond the standard.




(a)




(b)

Fig.6. FFT analysis (a) 5th and 7th (b) 11th and 13th

After connecting MCR into the circuit this dominant harmonics are mitigated. MCR provide low impedance path for dominant harmonics by tuning required inductor value with switching capacitor.

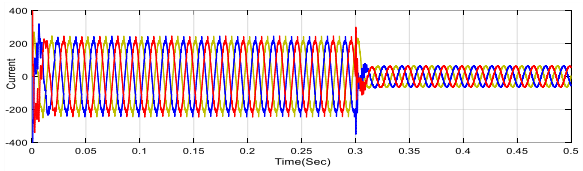
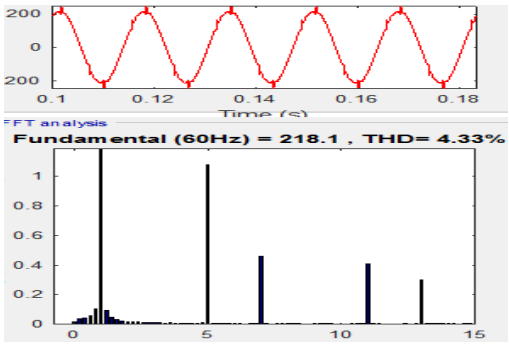
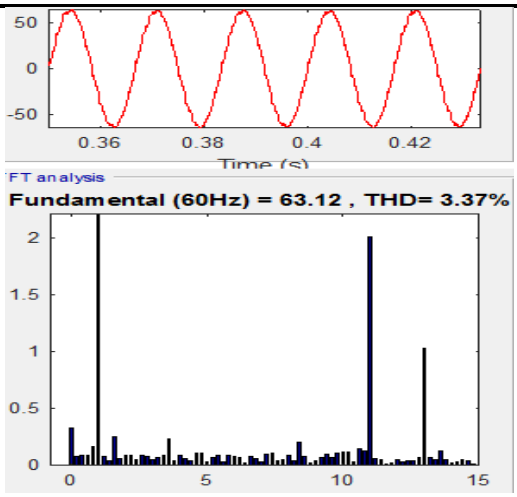



Fig.7. Waveform of phase A of load current (with MCR)




(a)




(b)

Fig.8. FFT with MCR

**Test Results**

Experiment being performed on single phase MCR prototype of 2.7mh. 95amp. Table1 gives detailed data regarding testing on MCR.

Table1. Measurement result

| Vac | Iac | Idc | mH | Hz |
|---|---|---|---|---|
| 59.05 | 70.2 | 0 | 2.641 | 49.98 |
| 50.4 | 68 | 15 | 2.36 | 49.98 |
| 42.11 | 68.2 | 31 | 1.966 | 49.97 |
| 35.63 | 69.2 | 44 | 1.639 | 49.98 |
| 20.12 | 71.2 | 57 | 1.302 | 49.98 |
| 21.011 | 72 | 72 | 0.929 | 49.96 |
| 14.115 | 77.8 | 95 | 0.578 | 49.97 |
| 13.8 | 76.8 | 103 | 0.572 | 49.98 |

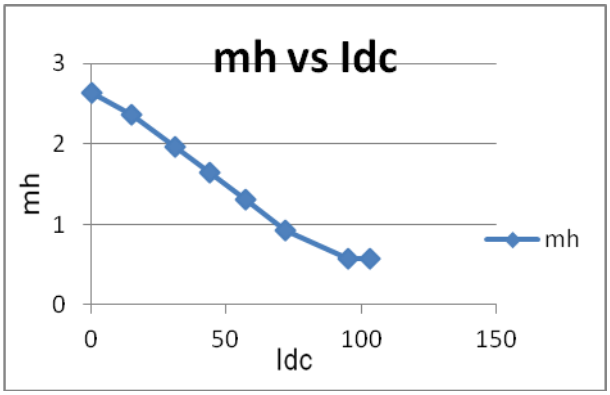



Fig8 – variation of inductance

The result shows the variation of L value with increase in DC current (fig 8). Hence it can be proved that value of L can be changed from 100% to 30% of the value.

## V. Conclusion

Harmonic is a very severe issue when it comes to power quality in distribution network. The use of different type of filter is incorporated in the system. The proposed filtering scheme has a advantage of low cost as compared to n-type of detuned filter. The use of magnetically controlled reactor for filtering application is properly demonstrated in this paper where inductance changes as to tune for mitigating dominant harmonics. This operation is based on magnetic saturation phenomenon in the iron core.

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