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ANALYSIS AND MITIGATION OF HARMONICS IN MEDICAL FIELD

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Abstract —*Among the various factors which causes poor power quality problems, harmonics are important one and Harmonics play significant role in deteriorating power quality, called harmonic distortion. Harmonic distortion in electric distribution system is mainly caused by the use of nonlinear loads. The rapid developments and use of nonlinear load leads to voltage and current harmonics, the controlling technique is important over the harmonic. Both passive and active filters have been used near harmonic producing loads or at the point of common coupling to block current harmonics. For harmonic compensation at medium/high voltage level Passive filters still dominate, whereas for low/medium voltage ratings active filters have been proclaimed. This paper presents an efficient model to compensate the current harmonics using the inverter based Active Power Filter, Passive Power Filter, and the combination of both. The system studies are carried for a medical center. The power flow studies are carried out to determine the data required to design the Capacitor banks The Medical Centre is analyzed for the harmonics through harmonic analysis based on which Active filters are designed. The study is conducted on Electromagnetic Transients Analysis Program (ETAP 12.6).*

Keywords- *Current and Voltage Harmonics, Active and passive filter, Power factor, mitigation*

I. INTRODUCTION

A Multispecialty Hospital getting Electrical supply from the electricity Board, this hospital commissioned with cardiology, neurosciences, orthopedics, nephrology and also having high level accuracy and separate measurement instruments. These hospitals have Generator, Ups and EB energy are used. An Electrical instruments connected in common grounding and neutral faced lot of problems due to harmonics. Harmonic is multiple of the fundamental frequency components in power system and are a result of non-linear electric loads. Harmonic frequencies in the power grid lead to power quality problems such as increased heating in the equipment and conductors, misfiring in variable speed drives, and torque pulsations in motors. Hence Reduction of harmonics is considered desirable.

1.1 CURRENT HARMONICS

Non linear loads such as rectifiers are main causes of Current harmonics. Non-linear load connected to the system draws non sinusoidal current. The current waveform depends on the type of load and its interaction with other components of the system. But practically it is possible to reduce the harmonic contents.

1.2. VOLTAGE HARMONICS

Voltage harmonics are caused by Current harmonics and the distortion the voltage provided by the voltage source the current harmonics depends on source impedance. For small value of the source impedance of the voltage source ,current harmonics will cause only small voltage harmonics. But the voltage harmonics are indeed small when compare to current harmonics. Hence , it can be approximated by the fundamental frequency of voltage. In this approximation method , the average real power contributed by current harmonics is zero and the current harmonics produce no effect on the real power transferred to the load. However, for consideration of higher harmonics of voltage, the current harmonics do make a contribution to the real power transferred to the load.

1.3 HARMONICS AND POWER FACTOR

Harmonic currents are caused by non-linear loads connected to the distribution system. The harmonics presence in electrical system distorts the current and voltage waveforms and it is deviated from sinusoidal waveforms. The major nonlinear loads are Switch-mode power supplies (SMPS), variable speed drives, photocopiers, personal computers, laser printers, fax machines, battery chargers and UPSs. The ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency component is known as total harmonic distortion (THD) .Harmonic Distortion is the interference in an AC power signal caused by frequency multiples of the sine wave. Total Harmonic Distortion is used as a measure of the amount of Harmonic distortion in the system.

A THD measurement shown in Fig: 2 can be made by applying a sine wave as an input to a system, and measuring the total energy which appears at the output of the system at harmonics of the input frequency.

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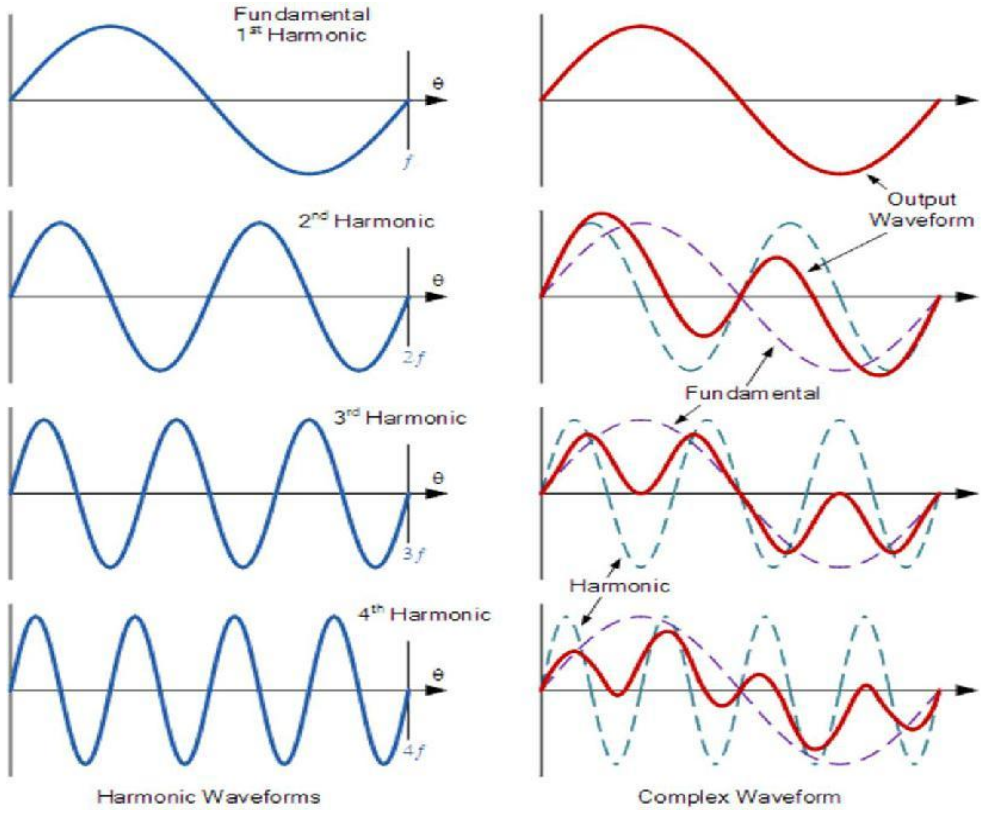

Fig 1.1 Harmonic Distortions

Table 1.1 Total Harmonic Distortions Limits

Bus Voltage At PCC Total Harmonic Distortion THD (%)	**Individual Harmonics (%)**	**Total Harmonic Distortion THD (%)**
V ≤1.0 KV	5.0	8.0
1.0 KV < V ≤69 KV	3.0	5.0
69 KV < V ≤ 161 KV	1.5	2.5
161 KV < V	1.0	1.5

Table 1.2 Total Harmonic Distortions Limits Pcc Based
Current distortion Limits for General Distribution Systems (120V through 69,000V)

Maximum Harmonic Current Distortion in Percent of load

I_{sc}/ Load	<11	11<=h<17	17<=h<23	23<=h <35	35<=h	**TDD (%)**
<20	4.0	2.0	1.5	0.6	0.3	5.0
20<50	7.0	3.5	2.5	1.0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0
Even harmonics are limited to 25% of the odd harmonic limits above						

I_{sc}=maximum short circuit current at PCC **L**oad= maximum demand load current (fundamental frequency component) at PCC

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II. ELECTRICAL SYSTEM

2.1 EXISTING SYSTEM

The Existing Electrical system used in a Hospital has been presented in Fig3.1 where Capacitor filter is used.

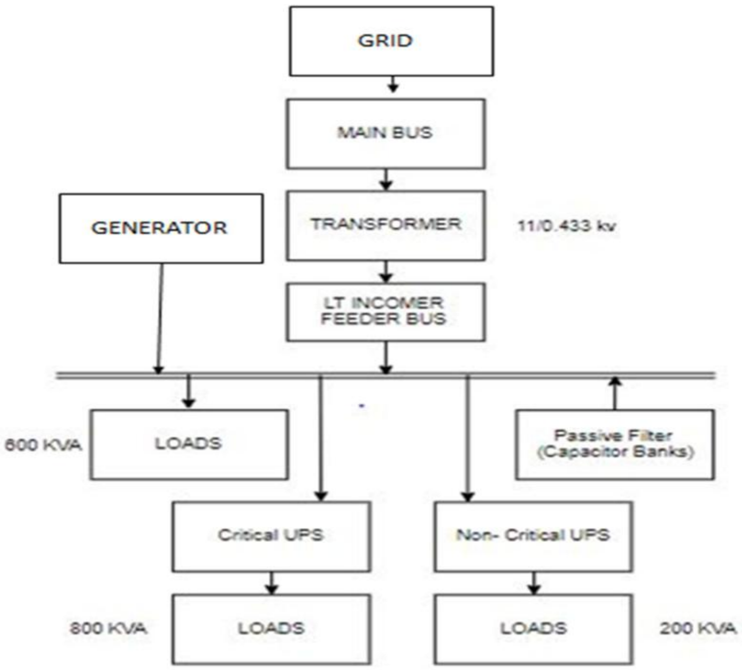

Fig 2.1 Existing System

UPS DETAILS:

Critical UPS : 120KVA,96KW,3PHASE,415VOLTAGE
Non Critical UPS : 20KVA,16KW,3PHASE 415VOLTAGE

Transformer rating :

Capacity : 1600 KVA
Primary Voltage : 11KV
Secondary voltage : 433 V
Primary current : 84
Secondary current : 2133.4 Vector
group : Dyn11
Current Ratio: Main in comer : 2500A/5A
Voltage Ratio: Main in comer : 1:1
Transformer Rating = 0.63 MVA
Transformer Voltage ratio =11/0.433 kV
Frequency=50Hz
Transformer Impedance=5% = 0.05 PUMV System fault level (Maximum)=40 kA
MV System fault MVA=√3 x 40 x 11 = 762 MVA
Total Impedance=0.63 / 0.0508 = 12.40

2.2 PROPOSED SYSTEM OF DETUNED CAPACITORS FOR POWER QUALITY IMPROVEMENT

Harmonic contents in loads can be reduced with existing load equipment. The applied voltage is lowered to correct range there by an over excited transformer can be brought back to normal operation. PWM drives used to charge the dc bus capacitor directly from the line without any intentional impedance are exception to this problem**.** Harmonics reduction and transient protection can be achieved by series connection of a line reactor or transformer. Fifth and seventh harmonics can be reduced significantly Phase shifting transformer connections The flow of zero sequence harmonics from the line can be blocked using Delta connected transformers. Automatic power factor correction system (APFC) is based on fixed and predefined amount of KVAR. But main priority is not given to APFC. Detuned capacitors are used as harmonic filters and its advantages over plain capacitors for power factor correction is presented. The various problems caused by harmonics and how filters prevent them are reviewed, and a comparison between them is also presented.

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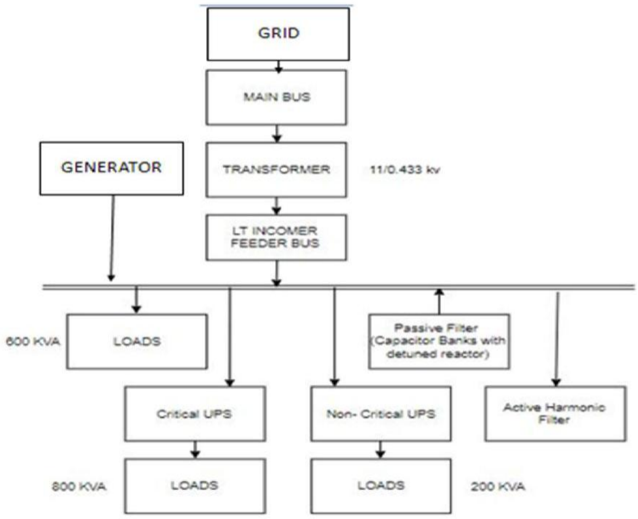

Fig 2.2 Proposed Electrical System Construction Block Diagram

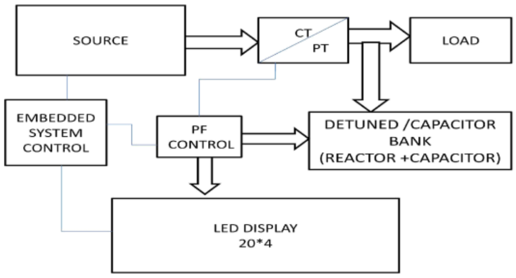

Fig 2.3 Passive Filter Construction Block Diagram

2.3 CALCULATING PERCENT IMPEDANCE FOR AN AC LINE REACTOR

The percent impedance value of the reactor depends on the percent of nominal voltage that would be dropped across the reactor and it is calculated with the rated current through it at fundamental frequency .As per the Ohm’s Law the voltage drop across the inductor

$E = I\ X_L$

$X_L = 2\pi\ f\ L$

Where: X_L Inductive Impedance

E Voltage (Volts)

I Fundamental Current (Amps)

f Fundamental Frequency (Hertz)

So the formula for Percent Impedance would be as follows:

$\%Z = L \text{ (in Henries)} / [(V_{L\text{-}L} / 1.732) / (I \times 2\pi \times f)] \times 100\ \%$

2.4 HARMONIC RESONANCE

The Harmonic currents that are generated by the operation of non linear loads in a distribution system flow throughout the power system .The inductive reactance of the power system increases and the capacitive reactance decreases as the frequency increases, or as the harmonic order increases. If capacitor exists in a system, there will be a crossover point at a given harmonic frequency where the inductive and capacitive reactances are equal. At this cross over point power system has coincidental similarity of system impedances and this point is known as parallel resonant point. Parallel resonant point exists at every system with capacitor.

2.4 How to Avoid Harmonic Resonance

Harmonic resonance can be avoided by using de-tuned harmonic filters or with the help of an appropriately sized capacitor .Harmonic filters provide the same 60-Hz reactive compensation as capacitors, but they're typically designed with a parallel resonance point below any expected harmonics on the system. Frequency scanning and harmonic resonance evaluation are performed to avoid resonance to ensure financial benefits of applying capacitive compensation technique.

2.6 DETUNED CAPACITOR BANK DESIGN DATA

- 5.5% Low Loss, Iron Core, Al wound, Highly Linear Harmonic Filter Series Reactor suitable for Permissible Over loading – 1.3 x Rated current
- Linearity – 1.8 x Rated current 75Kvar, 525 V, 3Ph, 50 Hz -10 No 37.5Kvar, 525 V, 3Ph, 50 Hz -2 No.

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2.7 NEED FOR DETUNING CAPACITORS

Non-linear loads in industry typically contain a high fifth harmonic. At the fifth harmonic, the tuned filter has a better behavior than the detuned filter. In order ensure the proper operation , the voltage rating of Capacitor bank must be higher than the voltage level required for detuned filters. Because detuned filters absorb less harmonics, they also carry lower harmonic currents than the tuned filters. These features make Detuned filters more.

2.8 ERECTION OF ACTIVE FILTER

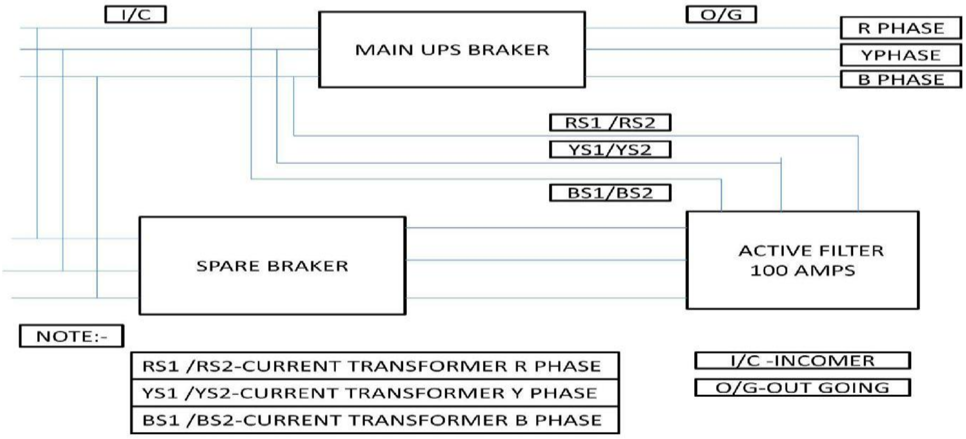

Fig 2.4 Active Filter Connection Block Diagram

Active Harmonic Filter/Active current conditioners are Static Compensator (STATCOM) based devices where compensating current of any shape or size are generated using an IGBT based inverter. Active Current Conditioners are used for reactive power compensation, harmonic mitigation, load balancing and neutral correction. They can be used for compensation on grid supply and are also fully compatible with DG operation.

Electronic power quality devices are designed to measure the load current and the variance from objectives set by the user is calculated to inject the right amount of current to make the supply current to meet the objective levels for harmonics, displacement PF, or load balancing. For harmonic mitigation, the load current is measured and harmonic current spectrum , amplitude and phase angle is calculated for every harmonic to the 50th order using appropriate logic. The amplitude to be injected at the opposite phase angle for each harmonic order selected for mitigation is determined by proper Logic. Based on that a control signal is generated and the semiconductors (IGBT) are directed to duplicate the control signal as injected current into the supply. Thus the supply side harmonic component of current is greatly reduced. The speed of response is controlled by: 1) the logic calculation method, 2) the switching rate of the IGBT and 3) the speed of the microprocessor in the control logic. The carrier frequencies and microprocessors are generally fast enough to provide per cycle response.

III RESULTS AND OBSERVATIONS

3.1 COMPARISON BETWEEN HARMONIC WAVE FORM WITH AND WITHOUT FILTERS

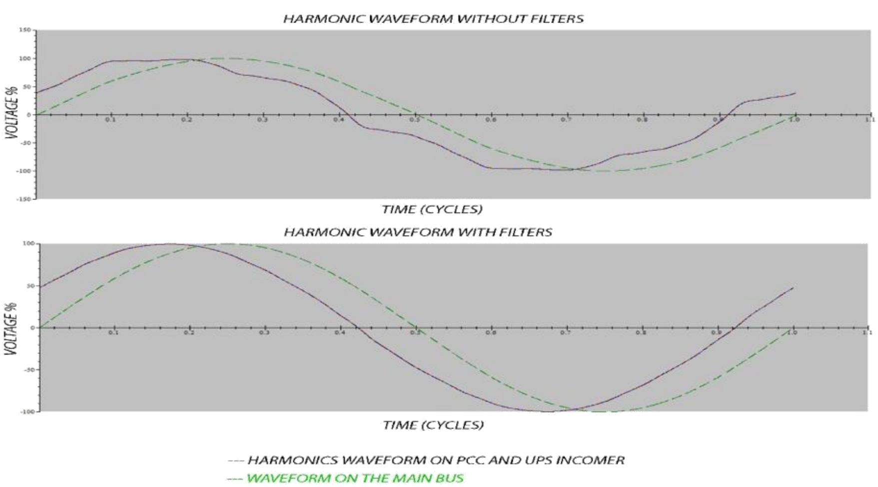

Fig 3.1 Harmonic wave form with and without filters

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3.2 PROPOSED ELECTRICAL SYSTEM (SINGLE LINE DIAGRAM)

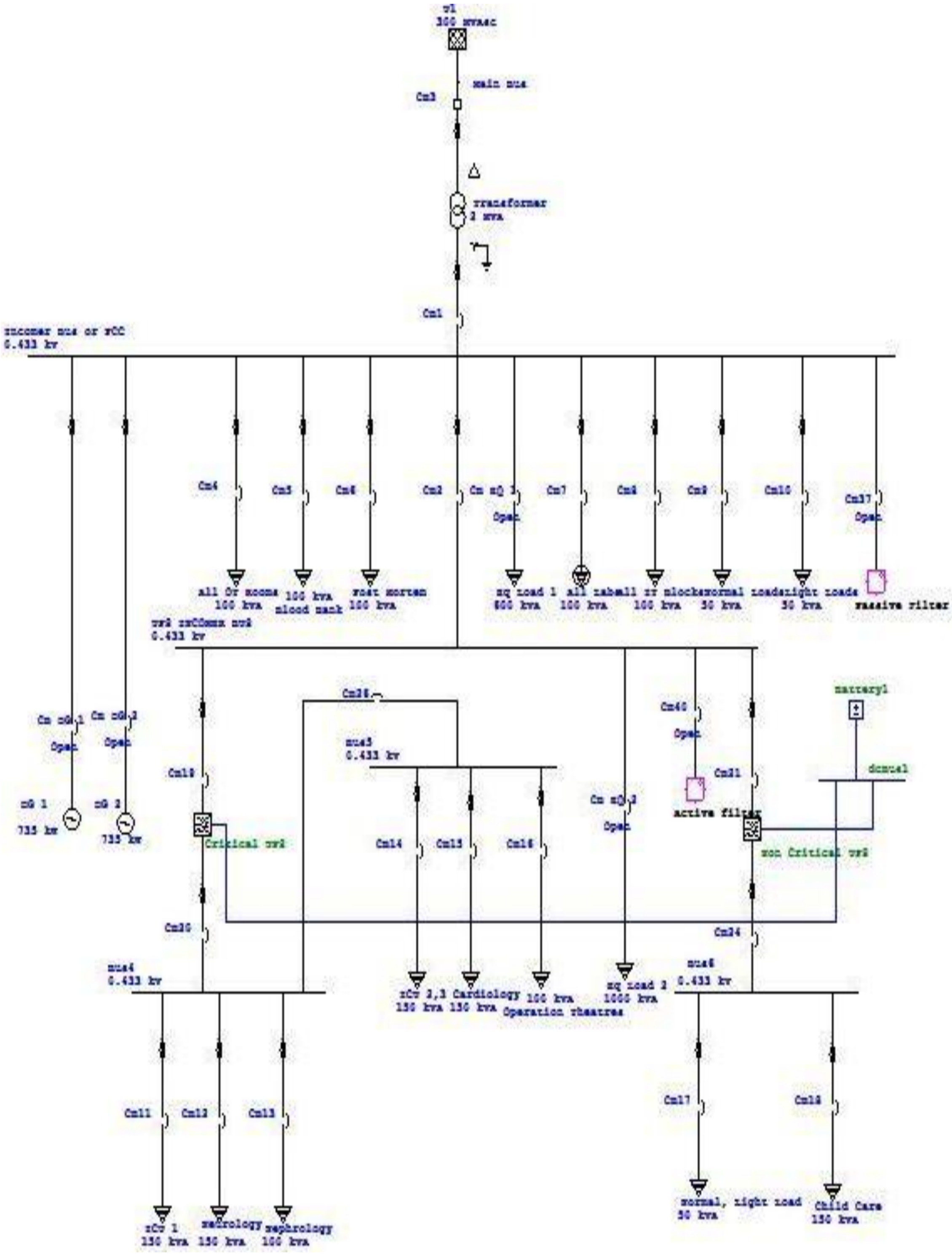

Fig 3.2 Proposed ETAP Diagram

The results obtained after the installation of the combination of active and passive filter is show in the table 7.1. It shows the comparison of results between the existing and proposed system.

COMPARISON OF RESULTS BETWEEN EXISTING AND PROPOSED SYSTEM

Type of System	Capacitor Bank				Passive Filter ON		Active Filter ON		Both Filters ON	
	OFF		ON							
	Power Factor	THD%	Power Factor	THD%	Power Factor	THD%	Power Factor	THD%	Power Factor	THD%
Existing System	**0.87**	**33.45**	**0.94**	**58.47**	Nil	Nil	Nil	Nil	Nil	Nil
Proposed System	Nil	Nil	Nil	Nil	0.98	10.25	0.84	2.28	**0.90**	**0.98**

Table 3.1 Comparison Of Results Between Existing and Proposed System

From the table 3.1 We can see that there is a significant difference in the Power factor and THD by replacing the existing system with the proposed system. The power factor improved from 0.87 to 0.90 and the THD reduced to 0.98% from 58.46% respectively.

IV CONCLUSION

The load flow studies were performed on the existing and proposed system .The harmonics observed in the existing system was above the standards given by IEEE and CEA. These harmonics not only affect the electricity board but also the sensitive and expensive analog equipment used. Therefore, a solution for both power factor correction and harmonic mitigation was found and implemented by installing appropriate combination of Active and Passive filters in the proposed system.

This improved the power factor very much and also the harmonics were brought to the standards.
The future scope of this project is that when a further expansion of the medical system takes place, the filters can be redesigned for the respective up gradations. Also, this technique of using a combination of Active and Passive filters together can be implemented in various systems which include Railway networks, Industries etc.

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