Study and Solution of Reactive Power Compensation, Harmonics Mitigation and Load Balancing for Power Factor improvement of Jaipur Metro Power Supply System using Active Harmonic Filters

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Abstract:- This paper presents a study and solution of different power quality issues of Jaipur Metro Rail Corporation (JMRC) power supply system. The measurement of different parameters was taken at 132kv incoming feeder of Jaipur Metro Receiving Sub Station. The measured data were analyzed and different power quality issues like excess reactive power; current harmonics and load unbalancing were observed. These power quality issues makes power factor poor. A solution of these power quality issues using Active Harmonics Filter has been proposed.

Keywords:- *Power Quality, Harmonics, Load unbalancing, Reactive Power, Power Factor, Active Harmonics filter, Non Linear Loads, Total harmonics Distortion (THD).*

I. INTRODUCTION

The Metro Railway network is increasing rapidly in India. The Metro Railways power supply system consist large cabling network which causes problem of excess reactive power. The metro railway loads are nonlinear and unbalanced due to single phase traction load which causes generation of harmonics and load unbalancing. Thus metro railways power supply system suffers with power quality issues like excess reactive power flow, harmonics and load unbalancing etc. These power quality issues makes power factor poor.

II. POWER FACTOR

Power Factor is the ratio of Useful Power (kW) to Apparent Power (kVA). The value of PF should be maintained at unity for reduced losses and optimum capacity utilization. The power Factors further can be classified as under [1], [2]:

A. True Power Factor (PF)

The True Power factor is the ratio of Active Power to the Apparent Power which is containing effect of voltage and current harmonics and load unbalance also. The presence of Voltage and Current harmonics makes the true power factor poor and is always less than Displacement Power Factor (Cos φ). The power supply utilities apply PF penalties/rebates on true power factor. Therefore to improve the true power factor is our main concern. The PF is given as:

$$PowerFactor = \frac{KW}{KVA} \quad (1)$$

B. Displacement Power Factor (Cos φ):

The Displacement power factor is the Cosine of angle between fundamental voltage and fundamental current waveforms. Thus simply the Displacement Power Factor is Cos φ of fundamental wave. Thus Displacement Power Factor is remains unaffected from voltage and current harmonics and is always greater than or equal to true Power factor.

C. Distortion Power Factor (DPF):

The distortion power factor term is introduced by the harmonics. The distortion power factor is given by:

$$\text{DPF} = \frac{1}{\sqrt{(1 + iTHD^2)}} \quad (2)$$

The True Power factor in terms of Displacement Power factor and Distortion Power factor is given by:

$$PF\ (True) = Cos\varphi \times DPF \quad (3)$$

The factors affecting the power factor are as under:

- Reactive Power
- Harmonics
- Load Unbalance

- *Reactive Power*

The relation of Active Power, Reactive Power and Apparent Power can be understood by Power triangle given below:

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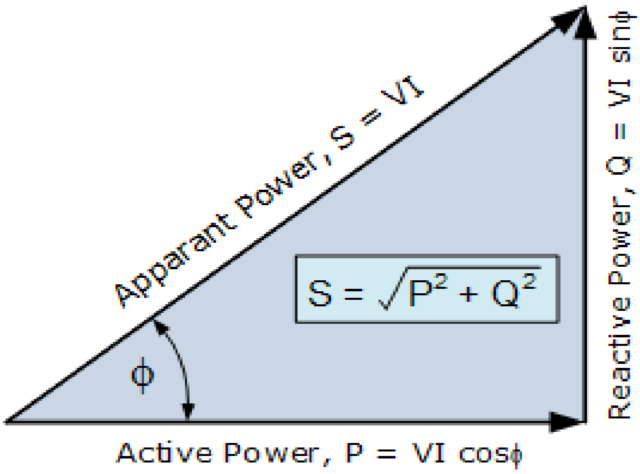

Fig 1:- Power Triangle

From the Power triangle, the Apparent Power is given by:

$$S^2 = P^2 + Q^2 \qquad (4)$$

Thus from equation (1) and (4) it can be concluded that Power factor is further depend on flow of Reactive Power. If the generation Reactive Power is equal to consumption of Reactive Power i.e. there is no reactive power flow in the network, then the system Power Factor will be unity.

- *Harmonics*

Harmonics are sinusoidal voltages or currents having frequencies that are multiples of the fundamental frequency at which the supply system is designed to operate. The harmonic currents generated by the load or more accurately converted by the load from fundamental to harmonic current have to flow around the circuit via the source impedance and all other parallel paths. As a result, harmonic voltages appear across the supply impedance and are present throughout the installation [3], [4].

- *Load Unbalancing*

Unbalance in a 3 Phase system is marked by a difference in the magnitude of current/voltage in different phases or when the phase separation is not 120 degrees. A balanced three-phase AC system acts like three independent single-phase systems. There's no neutral current, and the total active and reactive powers are just the arithmetic sum of the active and reactive phase powers. When there is any phase unbalance or harmonics, this classical (arithmetic) approach doesn't hold for apparent power. We need either IEEE 1459 or the Unified Power Measurement (UPM) method to calculate it. If the real power differs substantially from apparent power, the true power factor gets poor [5], [6].

III. SOLUTION OF POWER FACTOR IMPROVEMENT

The power factor of any system having power quality issues like reactive power flow, Harmonics distortion, load unbalancing and neutral current can be improved by Active power filter only. The Active Power filter is capable to fix all kind of power quality issues as discussed above.

A. Active Power Filter

The Active Power Filter's (APF) are voltage source converter based device which do not uses any passive elements for generation of reactive power. The Shunt APF is used for the harmonic currents, load balancing and reactive power compensation. Shunt APF consists of a three phase VSI with a capacitor which acts as a voltage controlled current source [7], [8].

IV. JMRC SUPPLY SYSTEM

JMRC receives power supply at 132KV at its Receiving Sub Station (RSS). JMRC have two RSS namely Mansarovar (MSOR) and Sindhicamp (SICP). 132KV supply is step down to 33KV, 3-Phase to feed auxiliary load of all metro stations and 25KV single phase to feed traction load for train operation. An overview of complete JMRC supply system has shown in fig. 2.

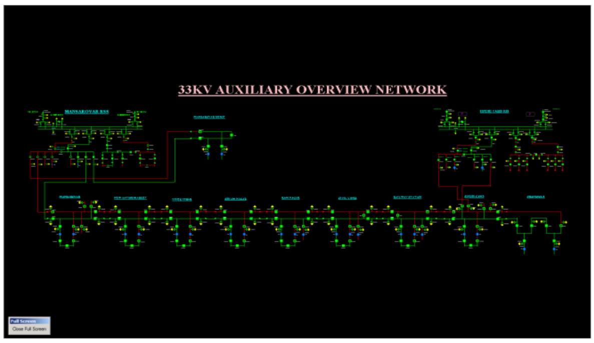

Fig 2:- JMRC Supply System Overview

V. MEASUREMENTS

The measurement of different parameters was taken using power quality analyzer at 132KV incomers of both RSS of JMRC. The graphs of measured parameters have given in fig. 3, 4, 5, 6 respectively.

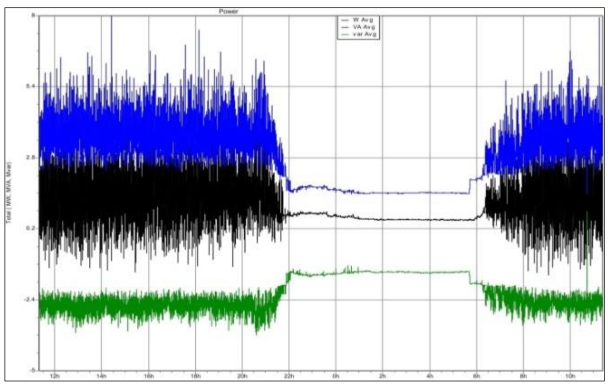

Fig 3:- Measurement of Power

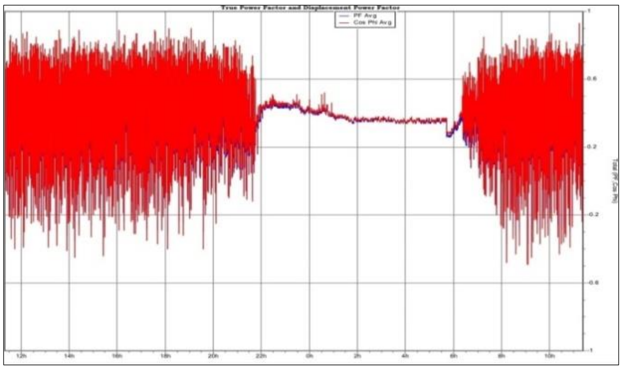

Fig 4:- Measurement of PF & DPF

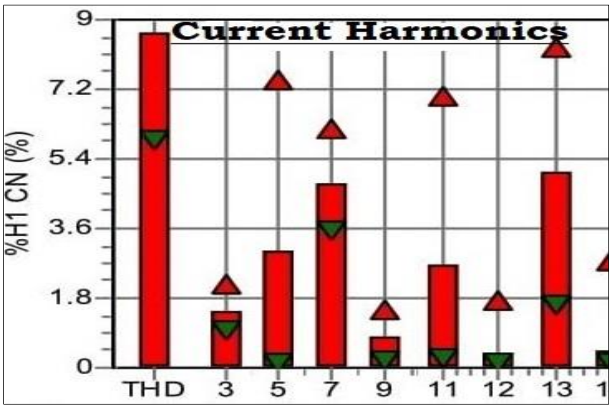

Fig 5:- Measurement of Harmonics

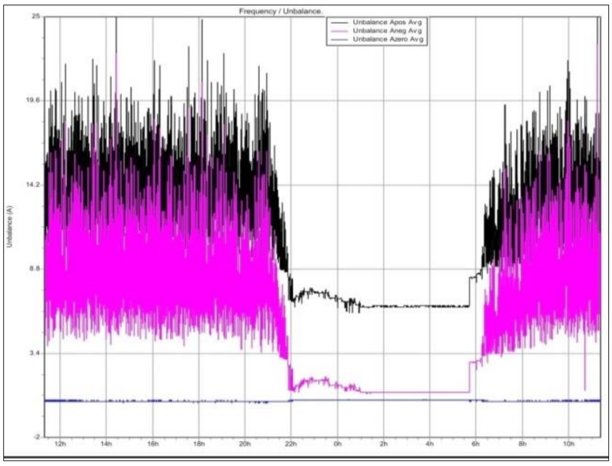

Fig 6:- Measurement of I (-)

A. *Measurement Summary*

Based on the measurement of Power, Power Factor, Harmonics and load unbalancing as shown in fig. 3, 4, 5 and 6 the measurement summary of different parameters has shown in below table:

S.N.	Parameter	MSOR	SICP
1	Active Power (MW)	3	2
2	Reactive Power (MVAR)	-2.7	-1.7
3	Apparent Power (MVA)	4.5	3
3	Power Factor	0.33	0.4
4	Cosϕ	0.37	0.45
5	iTHD (%)	10	12
6	Load Unbalance (%)	14	10

Table 1:- Measurement Summary

B. *AHF Rating calculation*

Based on the measurement summary, the AHF rating for mitigation of different power quality issues can be calculated as:

➢ *For Reactive Power Compensation*

The AHF current rating for Reactive Power compensation can be calculated as under:

$$A(AHF) = \frac{\text{Reactive Power(Q)}}{\sqrt{3} \times \text{AHF Voltage}} \quad (3)$$

Where Q is the required reactive power to be compensated and V is AHF voltage.

➢ *For Harmonics Mitigation*

Thus AHF current rating for harmonics mitigation at 415 voltages can be calculated as:

$$A(AHF) = \frac{\text{Current} \times \text{THDi} \times \text{Voltage}}{\text{AHF Voltage} \times 100} \quad (4)$$

➢ *For Load Balancing*

$$A(AHF) = \frac{\text{I(-)} \times \text{Voltage}}{\text{AHF Voltage}} \quad (5)$$

Based on the calculation of AHF ratings (A) as per equations (3), (4) and (5), the ratings of AHF have given in table 2.

S.N.	RSS	For Q	For iTHD	For I (-)	Total
1	MSOR	4174	890	4451	9515
2	SICP	2782	762	3186	6731
3	Both	6956	1653	7637	16246

Table 2:- AHF Rating

C. Proposed Scheme

Based on the AHF rating calculation, the proposed scheme of power factor improvement with location of Active Harmonic filter (AHF) has shown in fig. 7.

Proposed scheme of Reactive Power Compensation of Jaipur Metro with Active Power Filters

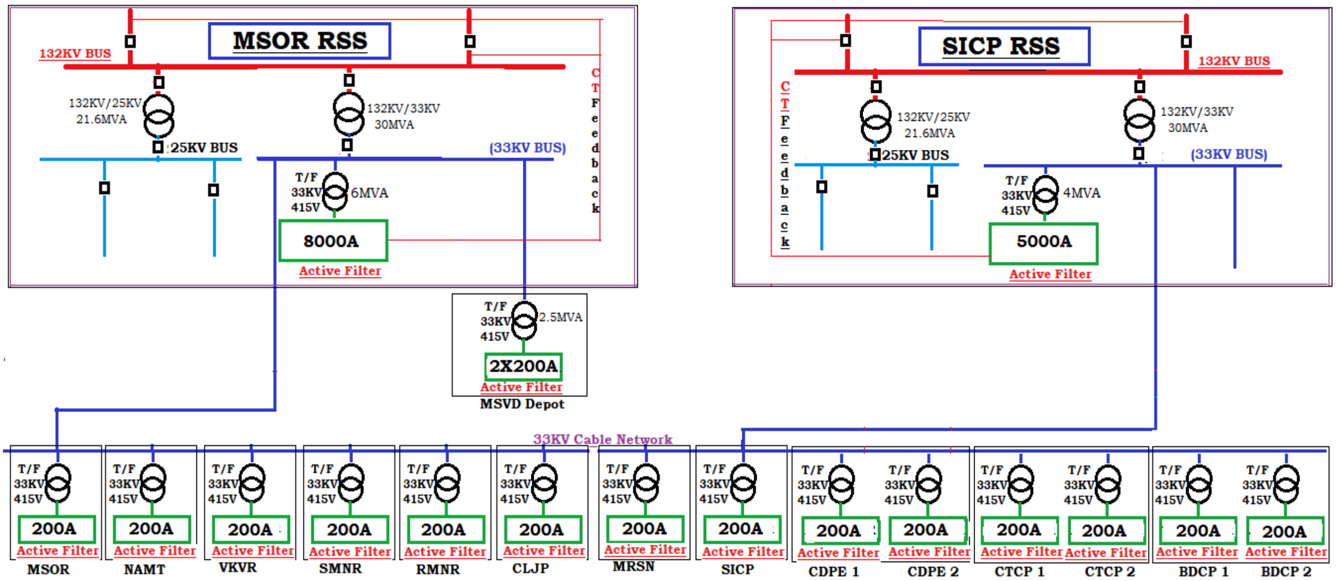

Fig 7:- Proposed Scheme

VI. CONCLUSION

From the study of a typical metro supply system for power quality improvement by Active Power Filter, the following conclusions are drawn:-

- Most of the loads connected to the system are non-linear which generates harmonics in the system.
- The single phase traction load causes load unbalancing.
- The use of cabling network causes generation of excess reactive power which causes power factor poor (leading).
- The JMRC load is dynamic in nature due to traction load. Therefore only dynamic compensation i.e. Active Power Filter can be used for Power Factor Improvement.
- Therefore to mitigate these all power quality issues which are causing power factor poor, Active Power Filter has been proposed at load level at 415V.

REFERENCES

[1]. P. Salmerón, J. R. Vázquez, R. S. Herrera and S. P. Litrán, "Apparent power and power factor in unbalanced and distorted systems. Applications in three phase load compensations" RE&PQJ, Vol. 1, No.5, March 2007.

[2]. Pragya Patel, Dharmendra Kumar Singh, "Evaluating Power Factor and Thd of Power Supply using Various Correction Circuits and Filters," International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181Vol. 3 Issue 12, December-2014.

[3]. António P. Martins, "The Use of an Active Power Filter for Harmonic Elimination and Power Quality Improvement in a Nonlinear Loaded Electrical Installation," RE&PQJ, Vol. 1, No.1, April 2003.

[4]. Sourabh Gupta, Preeti Gupta, "Harmonics Mitigation Using Active Power Filter," International Journal of Advanced Computer Research (ISSN (print):2249-7277 ISSN (online):2277-7970) Volume-3 Number-2 Issue-10 June-2013.

[5]. Zakir Husain, Ravinder Kumar Singh and Shri Niwas Tiwari, "Balancing of Unbalanced Load and Power Factor Correction in Multi-phase (4-phase) Load Circuits using DSTATCOM," Proceedings of the World Congress on Engineering 2010 Vol II.WCE 2010, June 30 - July 2, 2010, London, U.K.

[6]. DENISA RUSINARU, LEONARDO-GEO MANESCU, MARIUS MERFU, "The Load Unbalance Influence on the Power Factor Value in Three-Phase Distribution Networks," Recent Researches in Electric Power and Energy Systems ISBN: 978-960-474-328-5.

[7]. Randeep Singh Chib, Mehak Sharma, Hartaj Singh, "Active filter and reactive compensation using DSTATCOM" Randeep et al, Journal of Engineering Research and Studies E-ISSN0976-7916, J Engg Res Studies /IV/IV/Oct.-Dec., 2013/10-15.

[8]. Arun Shankar V.K., Senthil Kumar N., "Implementation of Shunt Active Filter for Harmonic Compensation in a 3 Phase 3 Wire Distribution Network," 1st International Conference on Power Engineering, Computing and CONtrol, PECCON-2017, 2-4 March 2017, VIT University, Chennai Campus.