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Analysis of Reactive Compensation at A 132/33 KV Grid Substation

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ABSTRACT: *Reactive power can be described as a by-product of electrical energy system. It circulates through the generators, cores of transformers, air gaps of motors and transmission lines, but it is not delivered anywhere. It must be recognized and accounted for, however, since it plays an important role in the stability, cost of power and maintaining voltage profile of the system. Reactive power is measured much like active power, that is, through a vector product of current and voltage. Reactive power does not vanish any energy other than the losses it generates through current circulation in the equipment and the transmission lines. Every kind of load except a perfect heating load generates reactive power. Reactive power can be leading (current vector leading the voltage vector) or it can be lagging (current vector lagging the voltage vector). Since reactive power can be leading or lagging, the net value must be zero. The leading power is because of capacitance in the power circuit. Similarly, the lagging power is because of inductance in the power circuit.*

KEYWORDS:*Reactive power,lagging and leading current vectors, lagging and leading voltage vectors,system stability,active power.*

I. INTRODUCTION

Reactive power can be described as a by-product of electrical energy system. It circulates through the generators, transmission lines and transformers, but it is not delivered anywhere. It must be recognized and accounted for, however, since it plays an important role in the stability, cost of power and voltage control of the system.

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II. NEED FOR MANAGEMENT OF REACTIVE POWER

In an integrated power system, efficient management of active and reactive power flows is of very importance. Quality of power supply is judged from the frequency and voltage of the power made available to the use. While frequency is measure of balance between power generated (and power available) and M.W. demand impinged on the system, the voltage is indicative and reactive power flows.

In a power system, the ac generator and EHV and UHV transmission lines generate reactive power. Industrial installation weather small or large are also the irrigation pump motors, water supply system draw substantial reactive power from the power grid.

The generators have limited defined capability to generate reactive power. Generation of higher reactive power correspondingly reduce availability of useful power from the generator.

During light load conditions, there is excess reactive power available in the system since the transmission line continues to generate the reactive power and this causes reactive power flows to the generator thereby raising the system voltage. For better efficiency it is necessary to reduce and minimize reactive power flows in the system.

Besides harmful effect, the reactive power flows also affect the economy adversely to the utility.If reactive power flows are reduced I^2R power losses as well as I^2X losses are reduced.It is therefore very clear that for efficient management of power supply and for improving the quality of power supply, it is essential to install reactive compensation equipment. Such installations are necessary and essential for utility. In fact the utility should be made responsible for making available only the active power to the next.

III. OBJECTIVE OF THE WORK

This Work Pertains to;"Shunt Compensation for improvement of Power Quality and Power Factor of load at a EHV Sub-Station"

1. Actual record of three parameters, namely, Bus Voltage, Load on Transformer and Power factor of load with one transformer in service under maximum load condition; With and Without Shunt Capacitor in circuit.
2. Assessment of improvement in Pf, Bus Voltage and reduction in load on transformer under conditions mentioned in serial number i) above.
3. Repetition of exercise mentioned in Sl.No.i) with two transformers in service and assessment of parameters mentioned in Sl. No. ii) under present conditions.

IV.REACTIVE POWER COMPENSATION

Electrical energy is generated, transmitted, distributed and utilized in Alternating Current System. However, major disadvantage of alternating current system is that the reactive power needs to be supplied along with active power. Active power contributes to energy consumed in loads but reactive power is an "imaginary" element which does not contribute to energy consumption.

Reactive power is consumed in power system elements and also by all loads as inductance is contained in all loads.. So, most appropriate definition for reactive power compensation is "Management of reactive power to improve performance of A. C. Power System".

Objectives of compensation

Basic purpose behind any given compensation to a system is to achieve one or more of the following objectives.

1. Reactive Power support and power factor improvement.
2. Reducing voltage drop in the line and thereby improving the voltage profile in the load condition.
3. Reducing voltage rise in the bus during low load condition.
4. Increasing load transfer capability of the system
5. Improving system stability.

(IV.I)Reactive Power Compensation Principle.

Reactive Power in a linear circuit is defined as that component of instantaneous power which has a frequency equal to 100 Hz in a 50 Hz system and the reason is that energy storage elements, inductors and capacitors store energy during quarter of a cycle, and send it back to source in next quarter and this sequence is repeated nonstop.

Thus, reactive power oscillates between source of supply and energy storage elements to and fro at 100 Hz i. e, twice of rated frequency. Therefore, reactive power can be compensated using VAR Generators and circulation between source and load can be avoided.

Two Angles to view reactive power compensation.

1. Load Compensation
2. Voltage Support.

Load Compensation

Load compensation has two objectives; i) Management of reactive power to improve voltage profile and load power factor & ii) Elimination of current harmonics produced by large fluctuating non – linear loads. In this case, reactive power flow is controlled by installing shunt compensating devices (capacitors/reactors) at the load end bringing about proper balance between generated and consumed reactive power.

Voltage Support

Reactive Power Compensation in transmission Systems improves stability limit of alternating current system by maximizing power transfer. It also helps in achieving acceptable voltage pattern.

V.SHUNT COMPENSATION PRINCIPLE

Figure on reverse depicts principle of shunt reactive power compensation. Sourcevoltage is V1, load voltage is V2 and load is purely inductive in nature. Load current has two components; IP & IQ. Component IP is in phase with V2 while component IQ is in quadrature as load is inductive. Load requires reactive power and this must be supplied by source. This increase total current on line i.e IL=IP+IQ and losses.

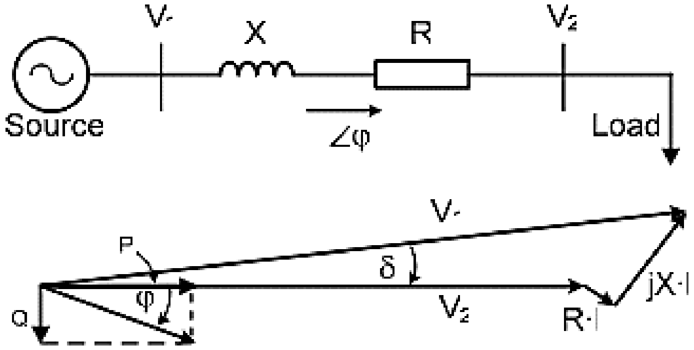

Figure 1 (a)

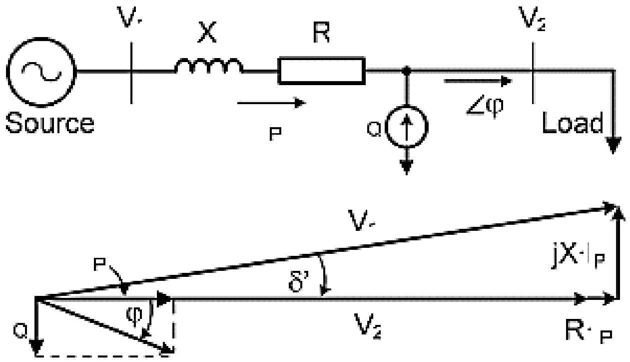

Figure 1 (b)

Fig. 1 a) Without reactive compensation b) With compensation

The remedial solution is to supply reactive power in one of following modes:-

1. Using a capacitor
2. Using a voltage source and
3. Using a current source.

In instant case a current source is used to supply current component IQ.
In doing so, following is achieved;

1. Total current component is reduced.
2. Voltage drop on line is reduced.
3. Load voltage V2 improves.

A current source or a capacitor is used when lagging reactive power compensation is needed and voltage source or an inductor is used when leading reactive power compensation is needed.

VI. CASE STUDY

132/33 KV, Madhotal Sub-Station on outskirts of Jabalpur city, is a recently commissioned Model EHV Sub-Station of M.P. Power Transmission Company and this Sub-Station initially had one number, 63 MVA, Bharat Bijlee
make, 132/33 KV, Transformer. This is a typical rural EHV Sub-Station of M.P. Transco wherefrom only light & fan loads of rural and urban areas were initially catered through four 33 KV feeders. A 12 MVAR Shunt capacitor was provided on 33 KV Bus for reactive power compensation. Subsequently, another 63 MVA transformer was added and few more outlets were created although compensation remained same.

This project was undertaken to assess if additional shunt compensation is needed consequent to commissioning of an additional 63 MVA Transformer, creation of few more feeders and additional load or the present reactive power compensation shall be adequate.

For this purpose, following three typical "maximum load" months were considered;

i) January'13 when only one 63 MVA unit was in service.
ii) December'13 when two transformers were in service &
iii) April'16 when again two transformers were in service.

The study covered record of following three parameters before and after the capacitor bank is put in service;

a. Power factor of load.
b. Load on Transformer.
c. Bus voltage.

1. Analysing the system with the help of MATLAB software.
2. Obtaining required Calculations of Energy Saving and power factor improvement.

Table 1.1 Detail of Components

Component	**Type**	**Rating**
Power Transformer	Transformer 1	63MVA
	Transformer 2	63 MVA
Feeders	Feeders 1	33 KV
	Feeders 2	33KV
	Feeders 3	33KV
	Feeders 4	33KV
	Feeders 5	33KV
	Feeders 6	33KV
	Feeders 7	33KV
BUS	132 KV aux. Bus	Single Zebra
	132 KV Main Bus	Twin Zebra
	33 KV Main Bus	Twin Zebra
	33 KV aux. Bus	Single Zebra
Capacitor Bank		12 MVAR

Case 1: Analysis for the January 2013

The following data has been considered for the study

Table 1.2 Data for the month of January 2013 (capacitor Bank off condition)

Name of Feeder	**Real Power (MW)**	**Reactive Power (MVAR)**
33 KV incoming 1	44	16
33 KV Marhotal	17	13.2
33 KV Katangi	16	1.092
33 KV Lema Garden	13.5	12.2
33 KV J.P. Nagar	8.9	3.9
33 KV Sever Plant SihoraPanagar	7.2	4.0

Table 1.3 Data for the month of January 2013 (capacitor Bank on condition)

Name of Feeder	**Real Power (MW)**	**Reactive Power (MVAR)**
33 KV incoming 1	42.6	8.0
33 KV Marhotal	15.4	9.2
33 KV Katangi	13.0	6.0
33 KV Lema Garden	12.6	6.2
33 KV J.P. Nagar	7.4	3.2
33 KV Sever Plant SihoraPanagar	5.4	3.0

Case 2: Analysis for the December 2013

The following data has been considered for the study

Table 1.4 Data for the month of December 2013 (capacitor Bank off condition)

Name of Feeder	**Real Power (MW)**	**Reactive Power (MVAR)**
33 KV incoming 1	23	8.7
33 KV incoming 2	25.6	12.6
33 KV Marhotal	13.9	7.2
33 KV Katangi	14.5	9.2
33 KV Lema Garden	12.8	7.9
33 KV J.P. Nagar	9.2	4.5
33 KV Sever Plant SehoraPanagar	13.9	5.1

Table 1.5 Data for the month of December 2013 (capacitor Bank “ON” condition)

Name of Feeder	**Real Power (MW)**	**Reactive Power (MVAR)**
33 KV incoming 1	21.4	5.6
33 KV incoming 2	23.4	06
33 KV Marhotal	12.8	6.4
33 KV Katangi	14.0	8.6
33 KV Lema Garden	12.4	5.8
33 KV J.P. Nagar	8.8	3.4
33 KV Sever Plant Sehora / Panagar	13.2	4.9

Case 3: Analysis for the April, 2016

The following data has been considered for the study

Table 1.6 Data for the month of January 2014 (capacitor Bank off condition)

Name of Feeder	**Real Power (MW)**	**Reactive Power (MVAR)**
33 KV incoming 1	20.1	8.2
33 KV incoming 2	22.3	9.59
33 KV Marhotal	16.2	10.9
33 KV Katangi	10.2	8.8

33 KV Lema Garden	13.2	10.2
33 KV J.P. Nagar	11.2	6.5
33 KV Sever Plant Sehora / Panagar	4.9	3.2

Table 1.7Data for the month of April 2016 (capacitor Bank on condition)

Name of Feeder	**Real Power (MW)**	**Reactive Power (MVAR)**
33 KV incoming 1	19.8	04
33 KV incoming 2	21.6	05
33 KV Marhotal	13.8	6.5
33 KV Katangi	9.6	6.4
33 KV Lema Garden	12.6	06
33 KV J.P. Nagar	11.0	3.2
33 KV Sever Plant SehoraPanagar	4.4	2.4

VII. RESULTS

The following results were undertaken during the case study. According to the results obtained from the study it is found that there is considerable increase in power factor as it can be achieve up to 0.93 from the value 0.7 when there is not existence of shunt compensation.(Figure 2.1)

The initial bus voltage is about 33 KV is further improved up to the maximum value of 33.5 KV in the month of January 2013. While using the capacitor bank it improves the bus voltage which is the good sign for reducing the power losses.(Figure 2.2) On the other hand there is considerable reduction in current which has on an average value of 850 as shown in figure 2.3.

Results January 2013

- Power factor improvement from 0.7 to 0.89.
- Bus Voltage improved from 33 KV to 33.5 KV.
- Sizable reduction in transformer load from 962.04 to 852.8 amp.
- The current is leading the voltage at an angle of 25.98° after putting on the Capacitor Bank while it was lagging about 30.6°.(Figure 2.1).

Results for December 2013

- Power factor improved from 0.7 to 0.931
- Bus Voltage improved from 32.3 KV to 33.1 KV.
- Load reduction; 1096.48 to 896.8 amp.
- Current found leading the voltage at an angle of 21.27° after putting on the Capacitor Bank while it was lagging about 26.54°.The lagging reactive power is responsible for low power Factor. (If the current legged the voltage it is known as lagging reactive power) (Figures 2.3).

Results for April 2016

- Power factor improved from 0.7 to 0.91
- Reduction in load; 1177.04 to 930.8 amp.
- Bus Voltage Improvement; 33 KV to 33.3 KV
- Current found leading the voltage at an angle of 24.21° after putting on the Capacitor Bank while it was lagging about 32.61°.(Figure 2.2).

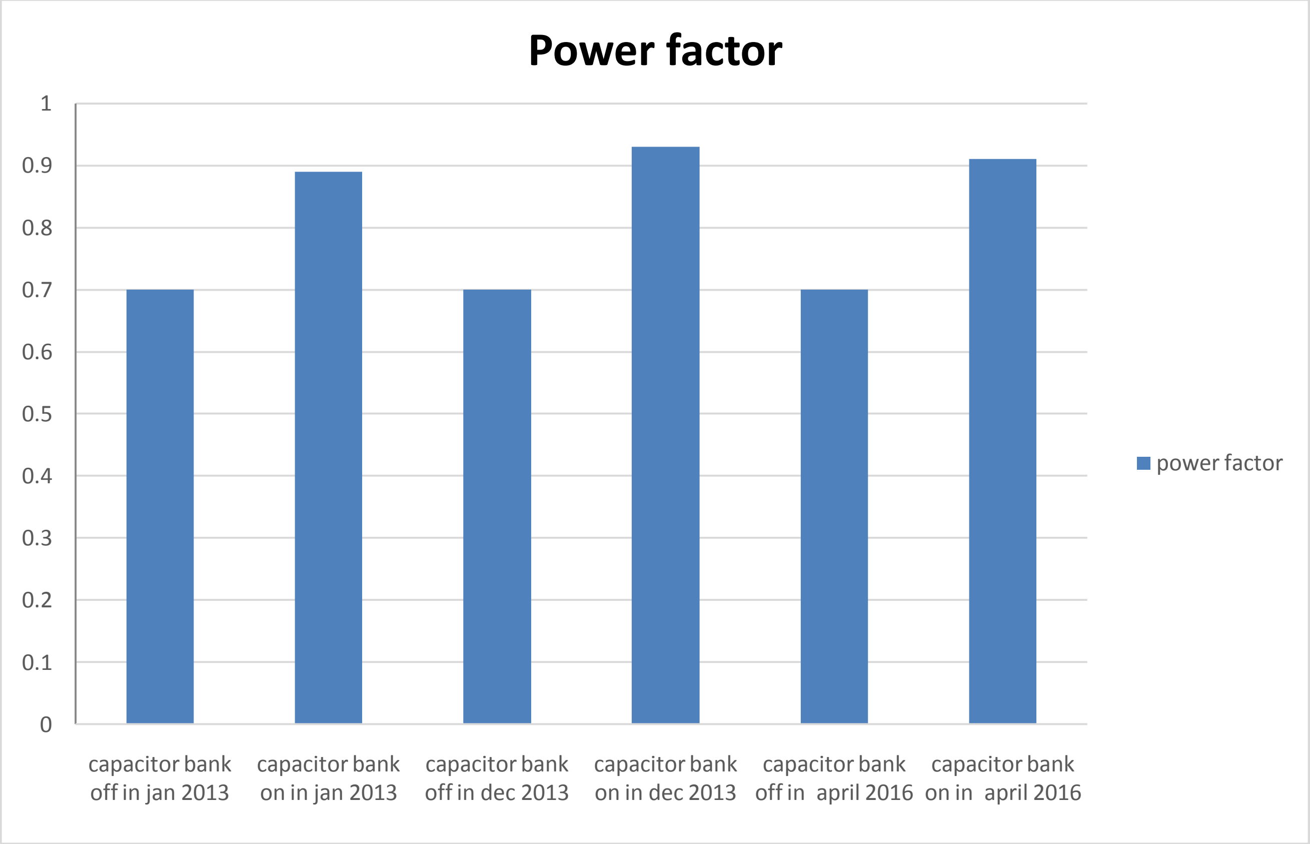

Figure 2.1 Power factor improvements

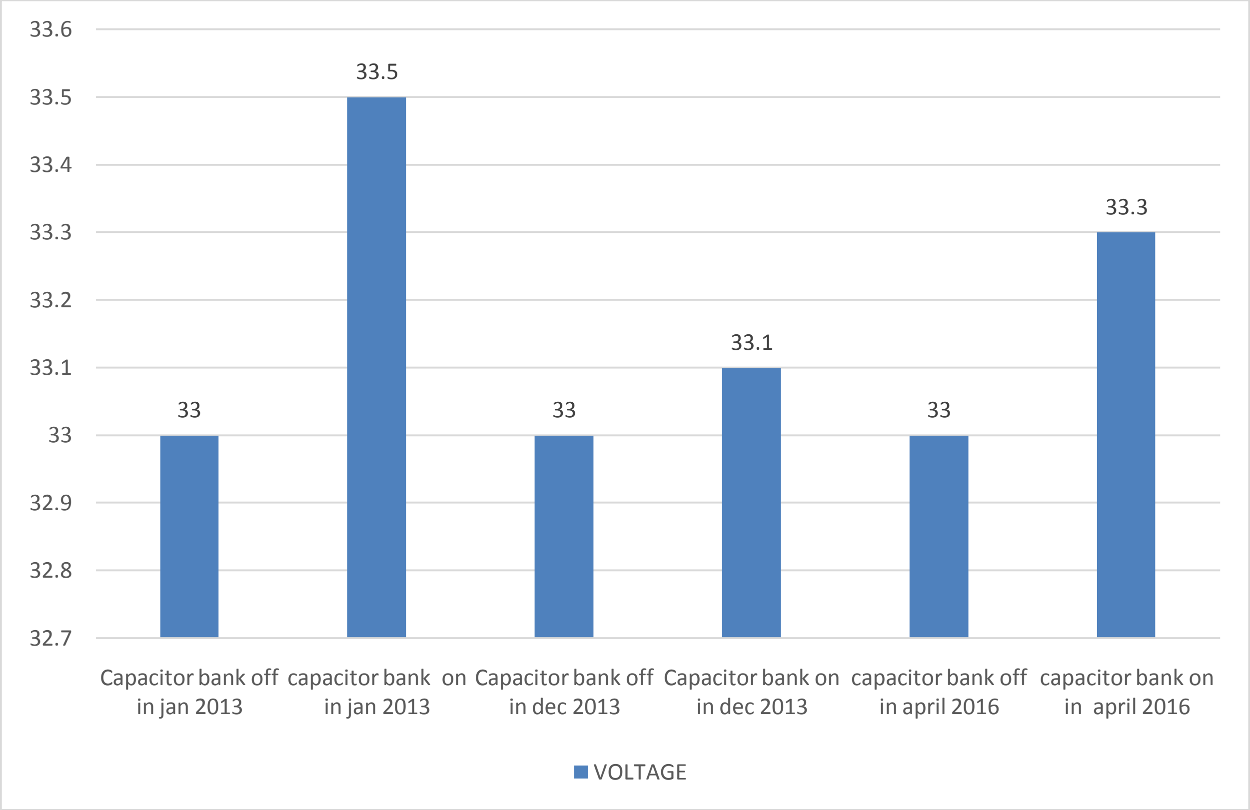

Figure 2.2 Bus Voltage Improvements

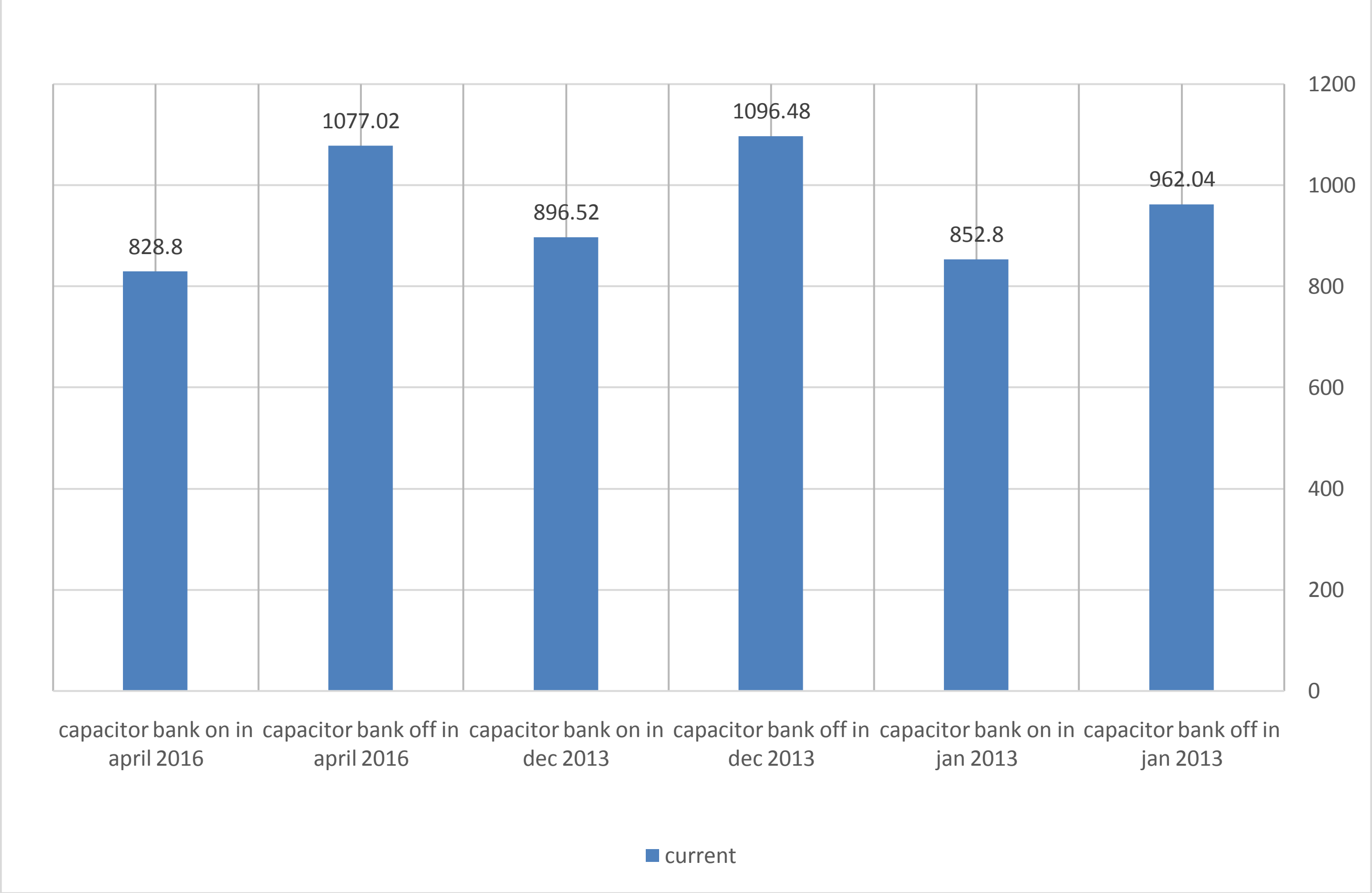

Figure 2.3 Reduction in current

VIII.CONCLUSIONS

The results reveal that the present reactive power compensation of 12 MVAR is adequate even though transformation capacity is augmented and loading increased.

- ✓ Considerable increase in Voltage and reduction in Current are observed.
- ✓ Power factor improvement is sizable i. e, from 0.7 to 0.9
- ✓ The present 12 MVAR Capacitor Bank is adequate and there is no need of augmentation in capacity of bank in near future even though an additional transformer and few 33 KV feeders have been added.
- ✓ Possible reason for this is connection of this Sub-Station with 220 KV Jabalpur and 132 KV Katni Buses which are considered strong Buses in light of their interconnections with three power houses, namely Vindhyachal Super Thermal Station, Amarkantak and Birsingpur.

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