

Impact of APFC Panel at LT Side of Transformer

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Abstract

The Development of automatic sensing technologies have significantly advanced in recent years in electrical systems. One of them is Automatic Power Factor Correction (APFC) Panels. It is very difficult to maintain consistent power factor by using fixed capacitors because they need to be operated manually which may result in over voltages, saturation of transformers etc. that may lead to the interruption in the power supply of the distribution system. APFC Panels automatically varies according to the load requirements on the L.T side i.e. distribution side which compensates the load requirements. Impact of automatic power factor correction panels (APFC) at L.T side of a transformer are discussed which are inductive in nature.

Key words: APFC Panels, Power Factor, Inductive, Fixed capacitors, Power factor correction.

I. INTRODUCTION

Most of the electrical loads are inductive in nature resulting in severely lagging power factor. The most practical and economical solution to improve the power factor (PF) is to provide reactive compensation by installing power capacitors of suitable rating at strategic locations. But this has to be operated manually and which may result in the over voltages, damage of the electrical equipments saturation of transformers etc. PF correction is more important in electrical distribution systems. For accomplishing the same low voltage (LV) capacitors are being extensively used both as fixed capacitor banks and in Automatic Power Factor Correction (APFC) Panels.

Application of APFC Panels is becoming more attractive due to their techno-commercial advantages like

- (1) Ability to maintain PF at the required high value (close to unity) and hence avoid the penalties imposed by electrical supply companies due to low PF
- (2) Avoid over compensation during low load conditions and
- (3) Improved efficiency of the system due to reduction in losses.

Application of automatic power factor correction panels (APFC) in electrical distribution network is gaining importance due to the advantages of APFC Panels over fixed capacitor banks like ability to maintain the target power factor with varying load and hence improve efficiency of the system and consequently reduce distribution losses.

At present, no comprehensive Indian standard is available for testing APFC Panels. Bureau of Indian Standards (BIS), the national standards body of India has extended financial support to CPRI to undertake a R&D project for development of a new standard for

LV APFC Panels. CPRI in association with APFC Panel manufacturers and purchasers has formulated an Indian standard for "APFC panels for voltage rating upto and including 1000 volts". The standard will help both manufacturers and utilities to setup uniformity in testing and also to install reliable APFC Panels for achieving the target power factor (PF), closer to unity and consequently improve the efficiency of the LV system by minimizing the losses in distribution systems.

II. METHODOLOGY

Present study has been conducted on APFC panels with contactor type of switching mechanism. Rating of the panels was 500kvar, 440V, 3-phase, delta connected. To improve the power factor using APFC panels, the following points have to be noted.

- (1) Please check if required kvar of capacitors are installed.
- (2) Check the type of capacitor installed is suitable for application or the capacitors are de-rated.
- (3) Check if the capacitors are permanently 'ON'. The capacitors are not switched off.
- (4) When the load is not working under such condition the average power factor is found to be lower side.
- (5) Check whether all the capacitors are operated in APFC depending upon the load operation.
- (6) Check whether the APFC installed in the installation is working or not. Check the CT connection is taken from the main incomer side of transformer, after the fix compensation of transformer.
- (7) Check if the load demand in the system is increased.
- (8) Check if power transformer compensation is provided.

Central compensation: Consumer installations usually possess a varying reactive power requirement. Unregulated fixed compensation is not possible in such cases since an uneconomical under-compensation or a dangerous over-compensation can occur. One must therefore continuously adjust the capacitor power to the required reactive power requirement.

One achieves this by means of automatic capacitor banks which are directly assigned to a switchgear unit, distribution and sub-distribution or to a large load with fluctuating reactive power requirements.

This is achieved in non-reactor protected systems by using special capacitor switching contactors. These are equipped with pre-charging resistors as a permanent component of the contactors. The capacitor is first connected to the network via these resistors by means of early closing contacts before the main contacts close. The inrush current is then only approx. 5% of the non-attenuated value.

Regulation, number of steps and control series : Most consumer installations are compensated using automatic capacitor banks due to the recognized benefits. The compensation power is designed with switched steps to match the employed capacitor power to the fluctuating load situation in the consumer's system.

A reactive power controller detects the momentary reactive power requirement by means of voltage and current measurements in the feeder to the consumer's installation (distribution or sub-distribution). The capacitor power is adjusted by connection or dis-connection in such a manner that a target power factor programmed at the regulators is reached.

To avoid the reconnection of capacitors that have not yet been discharged, certain switching or lock-out times are specified or pre-selectable in the reactive power regulator which are to be taken into account when choosing discharge devices.

The distribution of the total power among the switched regulator control taps [control outputs] is specified with the control series. It contains the number of steps and their power ratings as a factor of the power of the first step, which is defined as 1. The cross-sum of the control series gives the number of combination steps of the compensation system. For example, control series with four control steps of the same power: 1:1:1:1, the compensation system is regulated in $1+1+1+1=4$ combination steps. In this manner, it is possible to implement reactive power compensation systems, with which the number of steps is significantly higher than the number of control outputs at the reactive power controller.

Reactive power compensation systems are normally provided with 6 to 20 combination steps.

The graduation is too coarse with small number of stops, while more steps do not offer a significant improvement of power factor. Controllers with 8 control steps fulfill all practical requirements.

Power factor controller relay: Power Factor Controller relay (Model RPM-14) is designed for automatic control of capacitor banks in 3 phase 4 wire LT distribution systems. The relay maintains the system power factor at a set value, under fluctuating load conditions, by connecting or disconnecting capacitor banks to the 415V bus. The relay employs state of the art micro controller design for measurement of reactive power compensation required, system power factor, voltage and current. A specially formulated optimization program for capacitor bank switching ensures accurate power factor control at the set point and hunt free operation. RPM-14 is designed to control up to 14 capacitor banks.

Please refer wiring diagram shown below .

There are 4 groups of connections as explained below:

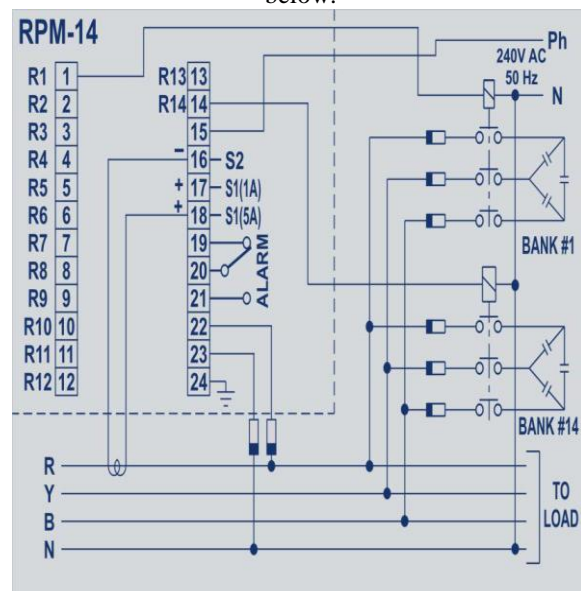


Fig.1 Wiring diagram of RPM-14 relay on APFC panel.

- Auxiliary supply to RPM-14:** Please connect R phase voltage of the capacitor bank panel to terminals 22 & 23 of the unit. Please note that it should be 240 V AC 50 Hz supply (Phase to neutral voltage). Phase is connected to terminal 22 and neutral is connected to the terminal 23 of the unit. RPM-14 uses this supply as the auxiliary supply for electronic circuit as well as measuring voltage for PF and KVAR computation.
- CT input to RPM-14:** The unit is suitable for connecting to CT secondary of either 1A or 5A

rating. Please ensure that the CT is on R phase.

CT secondary is to be connected as follows:

1A rating – Terminals 17 & 16

5A rating – Terminals 18 & 16

c) **Supply to Capacitor Bank contactor coil supply :** RPM-14 is meant for connecting up to 14 capacitor banks through external contactors. Consequently it provides 14 relay contact outputs.

- One terminal of all 14 contactor coils is to be connected to neutral of the contactor coil supply.

- The other terminal of each of the contactor coil has to be connected to RPM-14 terminals 1 to 14 as shown in the wiring diagram.

- The phase supply of contactor coil should be connected to terminal 15 of RPM-14.

d) **Alarm Circuit:** RPM-14 provides a change over contact at terminals 19, 20, 21. This is an 8A rated contact and can be used for energizing a buzzer.

Note: Please ensure that:

a) The auxiliary supply is 240 V AC

b) The CT is on the same phase as the auxiliary supply.

c) Earth connection to the relay is provided properly.

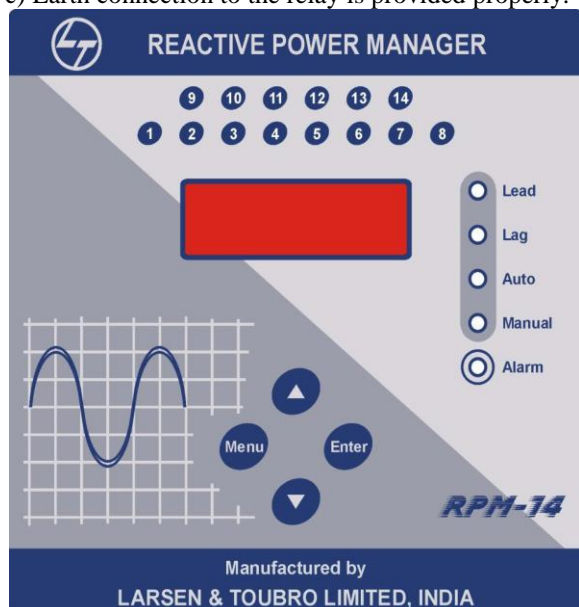


Fig.2: Power factor controller (RPM-14).

Capacitor bank selection:

The RPM-14 relay will continuously evaluate the required KVAR compensation and keep adding to the bus- thus bringing the plant PF close to the set value. Sometimes, in operation, RPM-14 may not find the closest match for the required KVAR and may stop adding. This may result in a PF much less than the set target.

In order that RPM-14 brings the plant PF closest to target PF, the system should have right denomination of capacitor banks as required by the load conditions of the plant. To determine, the right

denomination of bank sizes (14 in total), following approach may be followed:

Plant kVAR requirement >100kVAR		Plant kVAR requirement <100kVAR	
Bank no.	Size (kVAR)	Bank no.	Size (kVAR)
1	X	1	X
2	2X	2	X
3	3X	3	2X
4	5X	4	2X
5	8X	5	3X
6	10X	6	5X
7	15X	7	6X
8	20X	8	7X

Plant kVAR requirement >100kVAR		Plant kVAR requirement <100kVAR	
Bank no.	Size (kVAR)	Bank no.	Size (kVAR)
9	25X	9	8X
10	30X	10	9X
11	35X	11	10X
12	35X	12	11X
13	40X	13	12X
14	40X	14	15X

III. RESULTS

The experiment has been done in the National Small Industries Corporation (NSIC) industry in the industrial area of ECIL located in Hyderabad.

The details of the company without the impact of panel are:

Rating of transformer: 1500 KVA

Average power factor: 0.887

Connection type: 3-phase 5-wire

Average DPF: 0.851

The details of the company with the impact of panel are:

Rating of transformer: 1500KVA

Average power factor: 0.987

Average DPF: 0.948

CT ratio: 2500/1A
 PT ratio: 1:1

T R A N S F O R M E R					
S. No	PARAMETER	RMS			
		M I N	A V G	M A X	
1.	VOLTAGE	R	245.30	247.59	248.90
		Y	241.70	242.35	243.30
		B	246.00	246.856	247.90
2.	CURRENT	R	30.19	34.038	42.50
		Y	50.41	50.73	51.01
		B	38.06	38.87	39.91
3.	POWER(KW)	MIN			
			24.469	25.589	27.909
4.	POWER(KVAR)	29.116	30.324	32.383	
5.	POWER(KVA)	15.582	16.120	16.948	
6.	POWER FACTOR	0.827	0.837	0.860	

Table-1: Values with APFC panel

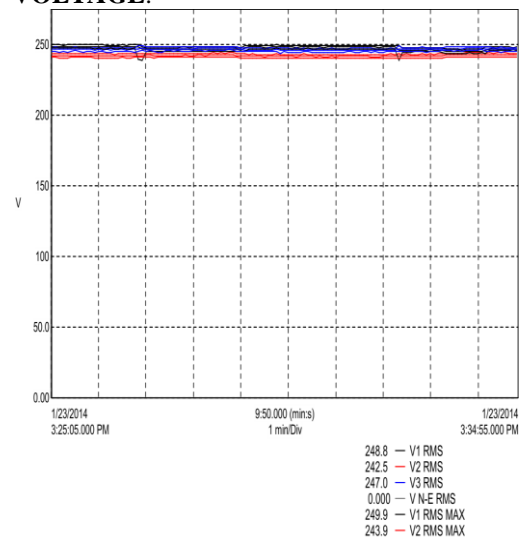
T R A N S F O R M E R					
S. No	PARAMETER	RMS			
		M I N	A V G	M A X	
1.	VOLTAGE	R	249.9	251.46	252.6
		Y	243.8	245.21	245.8
		B	248	250.01	251
2.	CURRENT	R	14.99	17.09	23.86
		Y	34.8	34.87	45.91
		B	23.31	24.045	33.28
3.	POWER (KW)	MIN			
			16.365	17.399	24.795
4.	POWER(KVAR)	-7.248	-6.602	-1.405	
5.	POWER(KVA)	18.126	18.865	25.411	
6.	POWER FACTOR	0.882	0.907	0.976	

Table-2: Values with out APFC panel

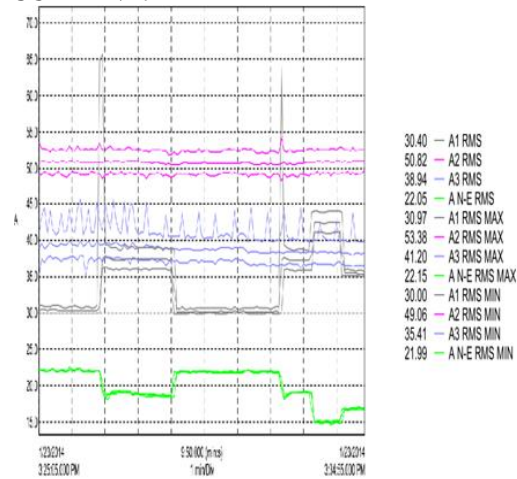
WAVEFORMS:

The corresponding waveforms of voltage, current, powers and power factor without the presence of the panel are shown below:

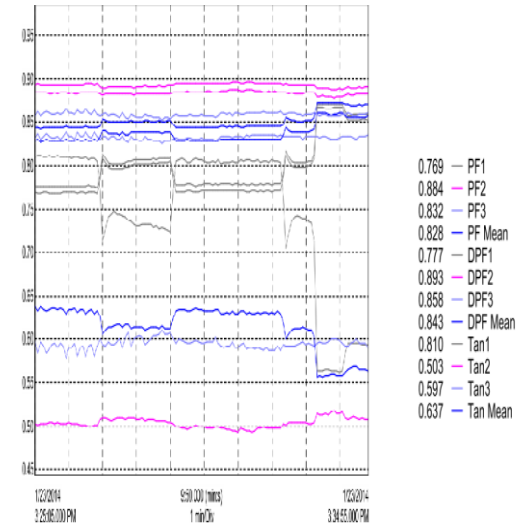
VOLTAGE:



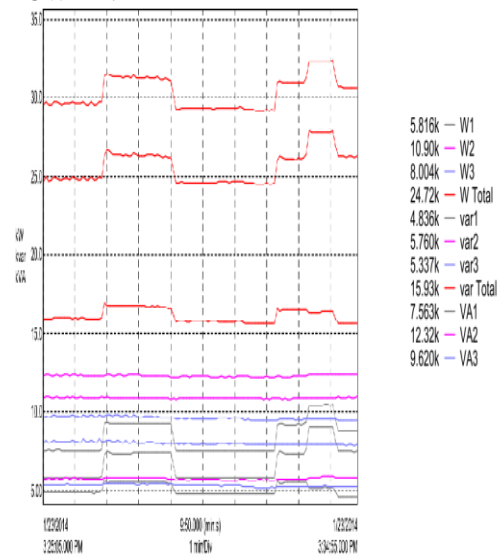
CURRENT:



POWER FACTOR :

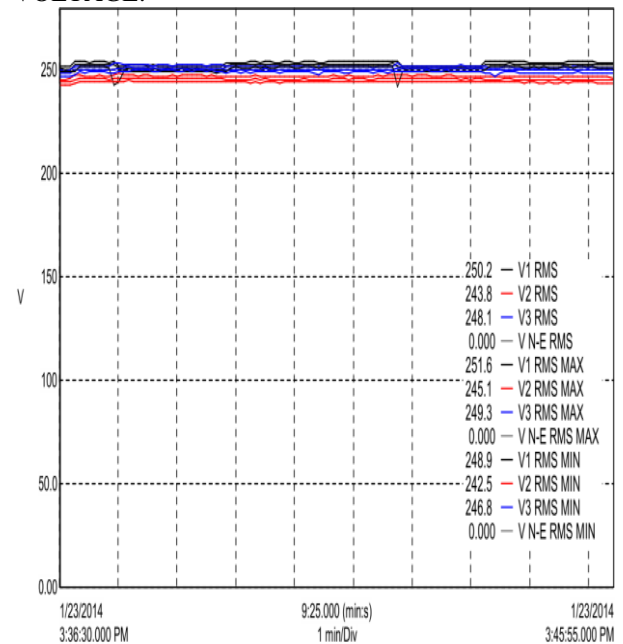


POWER :

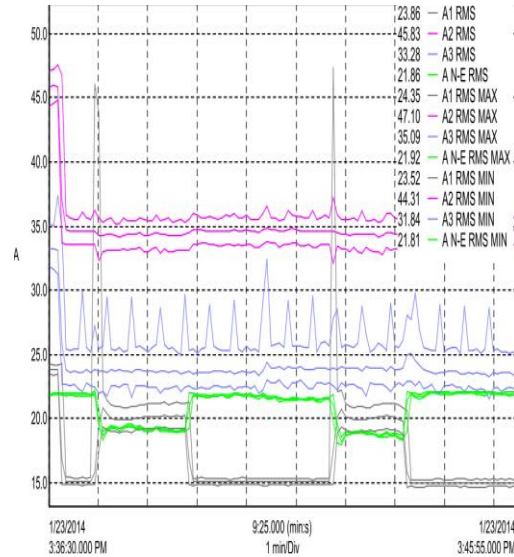


Similarly, the corresponding waveforms of voltage, current, powers and power factor with the impact of APFC panel are shown below:

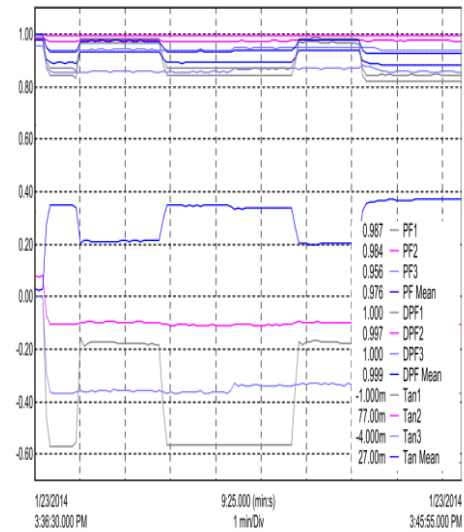
VOLTAGE:



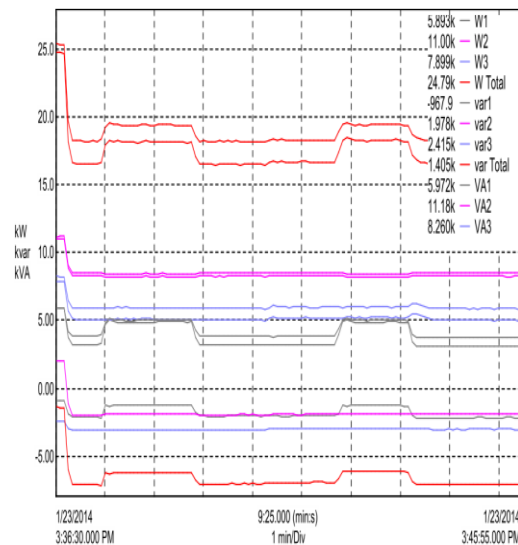
CURRENT:



POWER FACTOR:



POWER:



IV. CONCLUSIONS

The impact of contactor switched automatic power factor panels at low tension side of transformer has been studied at rapidly varying and scattered loads. Automatic switching operation of the panel was observed to be satisfactory, thereby, eliminating the need for manual intervention. The target power factor was also improved much better (0.88 to ~0.99) almost unity when compared to its absence, thus, reducing the effect of high power bills and heavy penalties from electricity boards.

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