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Design and Implementation of Automatic Power Factor Correction Panel

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Abstract: **We all know that Electricity is the driving force for the Industrial as well as domestic area in regular humans life in last few decades there are lots of research happen to find the way of efficient transmission of electricity and reducing the price of electrical billing one of the main cause of inefficient transmission of electricity and increasing rate of electricity billing is the reduction of power factor because overuses of inductive load. For efficient transmission of electrical energy power factor must need to be near to unity that problem can be solved by adding capacitive load but it is complicated to observe the value power factor regularly in certain instances of time and need a particular person to monitor and adding the load so that power factor maintain in specific limit means near to unity to tackle that problem smart control panel required that can continuously monitor the level of power factor and help to add and remove capacitive load to maintain power factor.**

Keyword: Power factor correction, reducing penalty in billing, smart control panel, Inductive load, capacitive load, efficient operation.

I. INTRODUCTION

Automatic power factor correction relay-based panel play vital role in measuring, controlling, and adjusting the power factor in Industries and it can be used in government and private offices where hues amount of inductive and large energy consumption devices use here APFC panel is used to reduces human efforts if we keep a particular person for this kind of task rather than this kind of panel then it will just like that we are saving money on electricity bills but spending money on skills person with less efficiency and we can't keep human for 24*7 working that why this kind of technology play very important role in this kind of area of work. Here APFC panel use a different kind of parameters as an input measure and adjusting it as per requirement. Power factor is nothing but the ratio between the Actual load power(KW) and the apparent load power(KVA) It is called usages of real power to the total power provided. Poor power factor will cause poor voltage regulation, it tends to increase copper loss, because of poor power factor conductors power handling capacity reduces, it tends to increase conductor size and much more. There are multiple ways of improving power factor some methods are expensive and some are economical system. Uses of the static compensator, use of the static capacitor, synchronous condenser, etc. are comes in the categories of high coast method its high coast is nothing but the one kind of disadvantages to overcome that problem new methods are developed which is much more depend on reactive power and this method is somewhere economical and more efficient compared to other kinds of methods. Automatic power factor correction panel is a very important method of transmission and utilization of Active power, the capacitance banks which is used in this panel plays a very important role in the improvement of power factor and it is less expensive it also can be one of the main reason behind its economical coast. The actual task of this panel to maintain the charge of capacitance within the specified limit so the power factor will get closer to unity for efficient power transmission and utilization. Theoretically, capacitance banks can give 100% of their KVAR value but practically it correcting power factor nearer to unity. Sometimes capacitor banks charge means leading load increase more than we need it also becomes the reason of inefficient transmission of active power and that tends penalty by the electricity service provider that means power factor must be in specified limit somewhere nearer to unity and APFC panel has that all component and applications to keep monitor and to correct power continuously.

II. DETAILS OF APFC

Utilization of power without APFC Panel

We all aware with the large amount inductive loads and hues amount of utilization of electrical energy in the industrial sector, most of the industrial loads are inductive which is lagging in nature, In industries because of its lagging nature and large operational period of time it makes poor to the power factor which depends on reactive power. Those reactive loads can be an electric motor, heaters, boiler, cooling fan, electric furnace, etc. That kind of load can lag the voltage by angles it may cause a reduction in power factor. This low power factor reduces the current carrying capacity of

conductors and tends to increase in the size of conductors this all happens because of poor power factor draws high terminal/internal current which can be the reason behind the generation of excessive heat in the electrical equipment which tends to poor voltage regulation and a large number of voltage drops.

Electricity boards our service provider company mark the penalty on the consumer's electricity bills which has a large amount of electricity bill with poor power factor. The value of the power factor can be reduced to the value 0.8 to 0.6 lag that directly affects the consumer's pocket in their electricity bills. The another main disadvantage of using large inductive equipment without APFC is poor power factor requires a large KVA rating for the equipment, the cost of large KVA rating devices is high which indirectly increases the cost of industrial equipment. This all disadvantage nothing but affect the big industrialist and small industrialist, APFC panel can play a vital role to eliminate this all problem.

III. PROPOSED METHOD

This system is specially designed to reduce human efforts in the industrial sector in the area of power factor correction, it consists of an APFC relay controller which is nothing but the most important device, In this method of controlling PF, it consists of sensing elements, display for observation, inbuilt to run overall system continuously.

Figure: APFC Relay module

IV. RELATED WORK

In below part of the paper consist of all essential part of consideration, system nature, design process and connection of the system

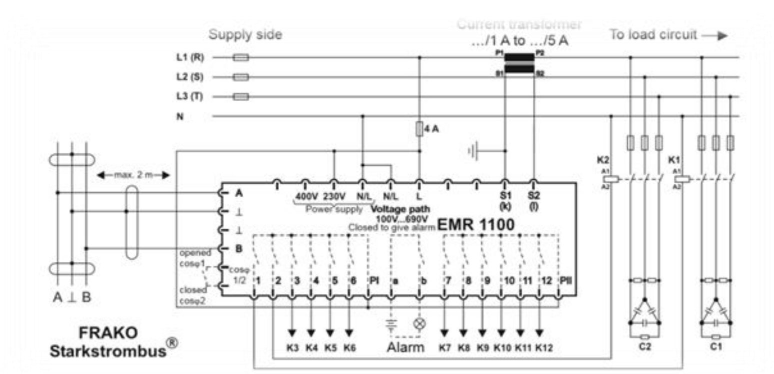

Figure: Circuit Diagram Aromatic Power Factor Correction Panel

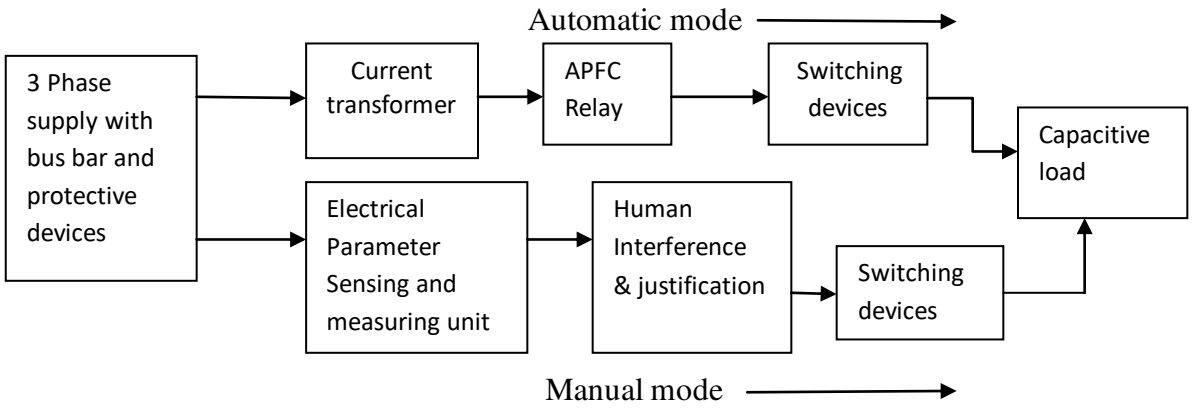

Figure: Block Diagram APFC Panel

a) APFC Relay

APFC Relay is nothing but the combination of controller and relay which is used for the controlling of overall operations of the APFC Panel by itself. APFC Relay is monitor and measures the power factor by calculating reactive power and compare it with the standard value of power factor which is pre-decided by the technician or skill persons in the industry APFC relay compare measure value and pre-decided standard value in the panel and it adds and removes the capacitance which is present in the capacitance bank keeping capacitance in allowable limit decided by the electricity boards or service provider. APFC relay consists of The inbuilt programming circuit, Value describing display, controlling keys, etc. traditional way of correcting power factor was a manual mode which is replaced by the APFC panel in the advancement of industries to remove the further drawbacks which are come with the manual mode of operation.

b) Placement of APFC Relay

The position and orientation of the APFC keep such a way that it will easy to accessible. APFC relay is mounting on the front side of the APFC panel for changing requires settings to controlling the APFC Panel. APFC Relay front side which displays side place outside of the panel and backside of APFC Relay where a large number of wires are available to connect to take control of overall functioning of the panel. Here front side or display of the APFC Relay is operating and correction making side and the Backside of the APFC relay is connection making side. APFC Relay is placed in such a way that it would be easy to make a connection with protective devices, Capacitance banks, CT, and many more components to reduce the length of connecting wires and to avoid the complexity occur by bundles of wire used in connection.

c) Protective section of the APFC Panel

APFC Panel dills with the large amount of incoming power so there will be lots possibilities of happing accidents like insulation failure, overloading, a large amount of heat production, short circuit or any kind of gross error can happen to avoid that all kind accidental error it is necessary to fix all standard protective devices. APFC Panel consist of Molded Case Circuit Breaker, MCB, which is the most common component which is used for overload protection, Bus bars is also the important devices of the panel which is used for providing power to the whole panel and it also helps to simplify the connections of panels, Isolators which connects before the installation is for disconnecting all phases if required, Current transformer which is to measure the current of another circuit, CT is generate or produce current in the secondary which is proportional to the current measure in the primary, sometimes in over safety In every electrical Panel where the large source of power is used lots of time, there will be the possibility of heat generation which can be dangerous if heat will increase beyond its limits that will affect another electrical equipments and can damage. APFC Panel power protective section design by keeping all this parameters in mind.

d) Capacitance Banks

In this project Capacitance bank is used for the reduction of the effect of inductive load on the power factor in other words it recovers the power factor which is reduced because of overuse of Inductive load in the industries. In

APFC Panel there are lots of Capacitance bank are used for converting lagging power factor to leading because capacitance is leading load, But sometimes power factor will get reach the much greater leading value that will also affect the efficiency power utilization and transmission which also to penalty so it is necessary to keep power factor near to unity. Relay and selector switch is used for adding and removing the capacitance banks which are control by the APFC devices. The Number of capacitance banks use depends on the number of stages of APFC relay use, In APFC all the Capacitance are connected in parallel to stabilize the power factor.

Calculation formulas of power factor cos φ and tan φ

$$\tan\varphi = \frac{Q}{P} \text{ or } \tan\varphi = \sqrt{\frac{1}{\cos\varphi^2} - 1} \text{ or } \tan\varphi = \sqrt{\frac{1}{\left(\frac{P}{S}\right)^2} - 1}$$

$$\cos\varphi = \frac{P}{S} \text{ or } \cos\varphi = \sqrt{\frac{1}{1+\tan\varphi^2}} \text{ or } \cos\varphi = \sqrt{\frac{1}{1+\left(\frac{Q}{P}\right)^2}}$$

e) Control and Operating Mode

In this project, there are two modes of operation

- Automatic Control Mode
- Manual Control Mode

1) Automatic Control Mode:-

Automatic mode of operation is the primary aim of this project, In this mode, the APFC Relay plays a very important role in power factor correction, here APFC Relay main controller which measures value power factor and it compares the actual value with the standard value which is pre-decided and set in the system it activates the number of relay for adding and removing the capacitance to improvise the power factor.

2) Manual Control Mode:-

In the simplest case, the capacitance is manually added in the system while the power factor is in poor condition to perform this operation the separate skill person is required to operate the appropriate sized capacitor is installed in parallel with each inductive load. This manual mode eliminates the additional load on the cabling in the system, this manual mode of operation is less costly because of fewer requirement devices as compared to the Automatic mode of operation. The drawback of this method is we can use capacitors only when the serviceman is available on the

site but without a person, we can't handle it whether power factor is leading or lagging, it's not easy to install the capacitors directly it also the time consuming inefficient process.

V. SELECTION CAPACITORS AND CALCULATION FORMULA's

Sr.no	Types of connection and Conditions	Formula	Example
1.	Capacitor power rating single-phase	$Q_c = C \cdot V^2 \cdot 2 \cdot \pi \cdot f_n$	Example: 83 µF at 400 V / 50 Hz 0.000083 · 4002 · 314,16 = 4,172 var = 4.17 kvar
2.	Capacitor power rating with delta connection	$Q_C = C \cdot V^2 \cdot 2 \cdot \pi \cdot f_n$	Example: 83 µF at 400 V / 50 Hz 0.000083 · 4002 · 314,16 = 4,172 var = 4.17 kvar
3.	Capacitor power rating with star connection	$Q_c = C \cdot (V/\sqrt{3})^2 \cdot 2 \cdot \pi \cdot f_n$	Example: 3 x 33.2 µF at 400 V / 50 Hz 3 · 0.0000332 · 2312 · 314.16 = 1.67 kvar
4.	Capacitor phase current	$I = \frac{Q_c}{V \cdot \sqrt{3}}$ or $Q_c = I \cdot V \cdot \sqrt{3}$	Example: 25 kvar at 400 V 25,000 / (400 · 1.73) = 36 A
5.	Series resonant frequency (fr) and detuning factor (p) of capacitors with filter reactors	$f_r = f_n \cdot \sqrt{\frac{1}{p}}$ or $p = \left(\frac{f_n}{f_r}\right)^2$	Example: p = 0.07 (7% detuning factor) in 50 Hz network fr = 189 Hz
6.	Capacitor power rating three-phase with filter reactors	$Q_C = \frac{C \cdot 3 \cdot V^2 \cdot 2 \cdot \pi \cdot f_n}{1-p}$	Example: 3 x 332 µF at 400 V / 50 Hz with detuning factor p = 7% 3 · 0.0000332 · 4002 · 314.16 / 1 - 0.07 = 53.8 kvar

VI. HARDWARE REQUIREMENT

- APFC Relay
- Capacitance Bank
- MCCB, MCB
- Duty Contactor
- Selector Switch
- Push Button
- Indicators
- Panel Box
- Voltmeter
- Ammeter
- Testing tools
- ON/OFF Button
- CT
- Connecting wires
- Bus bars

etc.

VII. APPLICATION

- It can be used in MSME
- It can be used in hospitals
- It can be used in privet and government offices
- Large industries
- It can be used in railways
- It can be used in colleges
- Automobile sector.
- Bank

Etc.

VIII. CONCLUSION

After studying the design of the APFC panel We can say that the APFC Panel plays a very important role in the area of power factor correction and making the system more stable, reliable, and efficient to utilize the power in industries or any place where a large number of electrical equipment use. Power factor correction techniques can be applied using for the small as well as large industries according to that their rating of apparatus will change in the system. In this project, several shunt capacitor banks were installed at the 440V line as a leading load. Increasing value Reactive tends to decrease power factor and Capacitor banks are used to reduce reactive power in the industries and substation for efficient operations and better value of power factor. This system gives an easy access of controlling and provides better solution on problem occurs in power factor correction.

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