IJAREEIE
e-ISSN: 2278-8875
p-ISSN: 2320-3765

# International Journal of Advanced Research

## in Electrical, Electronics and Instrumentation Engineering

Volume 13, Issue 5, May 2024

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 8.317

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 8.317|| A Monthly Peer Reviewed & Referred Journal |

||Volume 13, Issue 5, May 2024||

|DOI:10.15662/IJAREEIE.2024.1305035|

# Automatic Power Factor Control Panel Analysis

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**ABSTRACT**: In the present technological revolution power is very important, as the power demand in industrial and commercial load is increases. So we have to discover out the causes of control misfortune and progress the framework. Due to a variety of electrical and power electronics loads, the power system losses it's efficiency, hence causing leading and lagging power factor which gives heavy penalties to consumer by electricity board and also pollute the system environment. So we need to improve the power factor of the electrical system. It can be improved by using APFC system which can maintain constantly high power factor nearer to unity. Most of the load used in industries are inductive in nature due to this they consume reactive power which will affect the generation of plant. But in our ICEEM collage the load is capacitive so the power factor is in leading. The motive of this project is to build an Automatic Power Factor Control (APFC) panel, which is able to control the energy consumptions of a system and Automatically improve its power factor.

**KEYWORDS**: Power factor, APFC system, Power factor correction, System efficiency, Capacitive load.

## I.INTRODUCTION

In the present situation, power factor is one of the most precious and major issue. Any electrical load that operate on AC system that need apparent power, but apparent power is addition of active power and reactive power, but load consumed active power. Also, reactive power is important for load, because reactive power is the power required by the load and it get return to the power source.

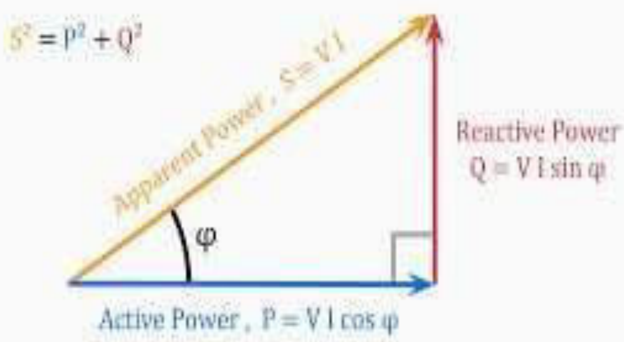


Fig.1.1 Power Triangle

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$$\text{Power factor } \cos\emptyset = \frac{\text{Active power}}{\text{Apparent power}} = \frac{KW}{KVA}$$

Power factor is ratio of the active power(KW) to the apparent power (KVA) drawn by an electric load. It has been a limited effect on how current is being converted into useful work output and due to the good indicator the load current has effect on the efficiency of the supply system. In collage most of the load i.e. computer, UPS, etc. causing leading power factor that's why there is loss and wastage of energy which result in high power billing and heavy penalty from electricity department. If the load is unbalanced it is complicated to maintain nearer to unity power factor. To solve this difficulty APFC panel is being used which keeps unity power factor. So many commercial and industrial loads need automatic power factor control system. In present time the cost of the electricity is higher, therefore it is important to compensate the electric power for reducing cost.

## II. SYSTEM MODEL AND ASSUMPTIONS

Main meter readings on 19 April and 20 April

| | 19 April | | 20 April |
|---|---|---|---|
| | 10AM | 5PM | 10AM |
| KWh | 184385 | 184430 | 184674 |
| KVAh | 287724 | 287836 | 288331 |
| KVARh | 188809 | 188908 | 189337 |

Table no. 3.1 Main meter readings on 19 April and 20 April Power Factor during 10 am to 5 pm on 19 April.

KWh = 184430 – 184385 = 45KWh KVAh = 287836 – 287724 = 112KVAh

Power factor = $\frac{KWh}{KVAh} = \frac{45}{112}$ = 0.40 lead

Power Factor during 5 pm on 19 April to 10 am 20 April. KWh = 184674 - 184430 = 244KWh

KVAh = 288331 – 287836 = 495KVAh

Power factor = $\frac{KWh}{KVAh} = \frac{244}{495}$ = 0.49 lead

**Main meter readings on 22 April and 23 April**

| Ratings | 22 April | | 23 April |
|---|---|---|---|
| **Time** | **10AM** | **5PM** | **10AM** |
| **KWh** | **185402** | **185508** | **185799** |
| **KVAh** | **289712** | **289905** | **290456** |
| **KVARh** | **190480** | **190635** | **191102** |

Main meter readings on 22 April and 23 April Power Factor during 10 am to 5 pm on 22 April.

KWh = 185508 – 185402 = 106KWh KVAh = 289905 – 289712 = 193KVAh

Power factor = $\frac{KWh}{KVAh} = \frac{106}{193}$ = 0.54 lead

Power Factor during 5 pm on 22 April to 10 am 22 April. KWh = 185799 - 185508 = 291KWh

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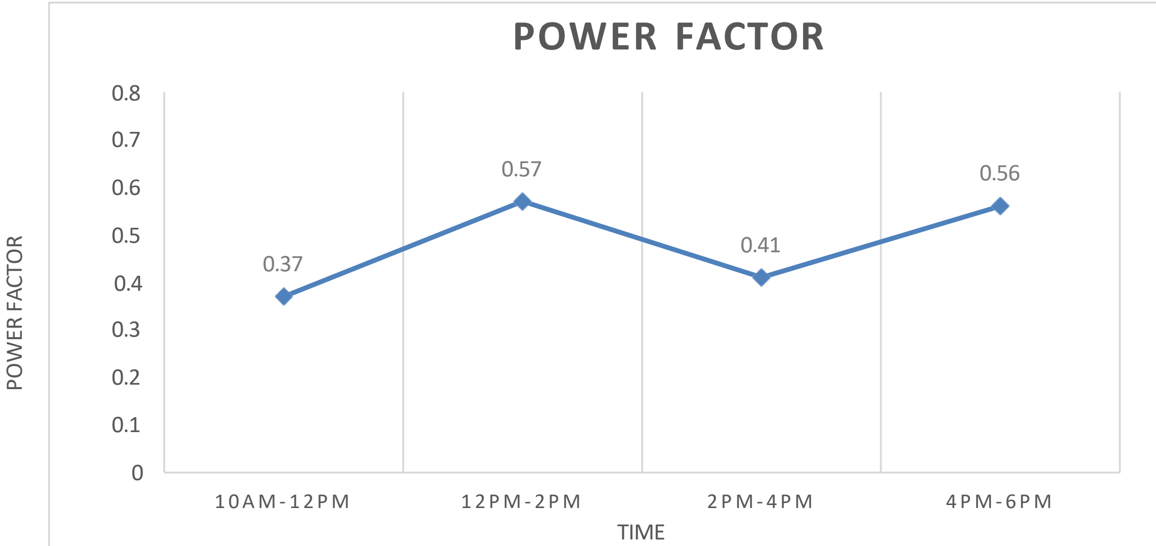
KVAh = 290456 – 289905 = 551KVAh

Power factor = $\frac{KWh}{KVAh} = \frac{291}{551}$ = 0.52 lead

Main meter readings on 22 April at every 2 hours' interval

| | 10AM | 12PM | 2PM | 4PM | 6PM |
|---|---|---|---|---|---|
| KWh | 185799 | 185818 | 185842 | 185864 | 185900 |
| KVAh | 290456 | 290507 | 290549 | 290602 | 290666 |
| KVARh | 191102 | 191148 | 191181 | 191227 | 191279 |

Table no.3.3 Main meter readings on 22 April at every 2 hours interval




Power Factor on 22 April , on interval of 2 hrs.

Table no.3.4 LT panel readings on 22 April

From June 2023 to March 2024 average monthly power factor

| | 10AM | | | 12PM | | | 2PM | | | 4PM | | | 6PM | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I (a) | V (v) | W (kw) | I (a) | V (v) | W (kw) | I (a) | V (v) | W (kw) | I (a) | V (v) | W (kw) | I (a) | V (v) | W (kw) |
| R | 39 | 445 | 9.4 | 52 | 450 | 12.50 | 62 | 450 | 15 | 54 | 450 | 11 | 22 | 450 | 3.6 |
| Y | 42 | 445 | 10 | 50 | 450 | 12.50 | 57 | 450 | 13 | 56 | 450 | 11.5 | 18 | 450 | 1.9 |
| B | 45 | 445 | 10 | 48 | 450 | 11.50 | 56 | 450 | 13.5 | 47 | 450 | 13 | 22 | 450 | 2.4 |

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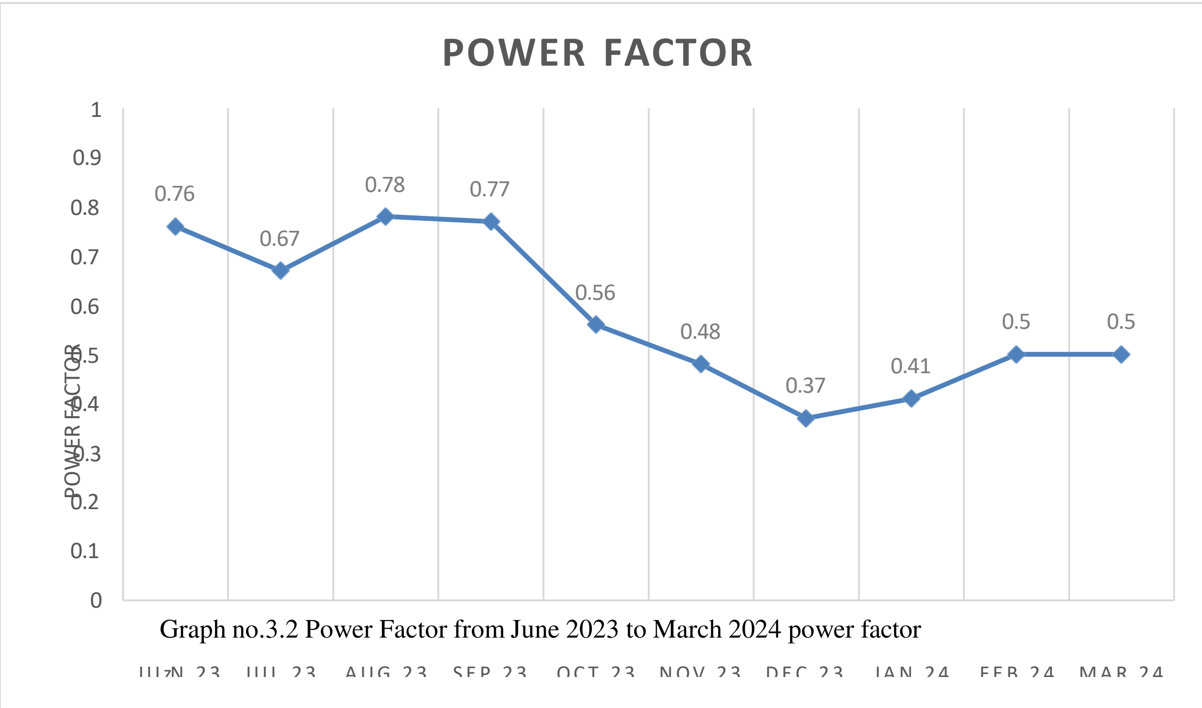
| Months | Power factor |
|---|---|
| June 2023 | 0.76 |
| July 2023 | 0.67 |
| August 2023 | 0.78 |
| September 2023 | 0.77 |
| October 2023 | 0.56 |
| November 2023 | 0.48 |
| December 2023 | 0.37 |
| January 2024 | 0.41 |
| February 2024 | 0.50 |
| March 2024 | 0.50 |

Table no.3.5 From June 2023 to March 2024 average monthly power factor June 2023 to March 2024 average monthly power factor graph From




Graph no.3.2 Power Factor from June 2023 to March 2024 power factor

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Observation readings and penalty form july 2023 to march 2024

| Months | KWh | KVAh | Average Power Factor | Penalty in Rupees |
|---|---|---|---|---|
| July 2023 | 95794 | 115438 | 0.67 | 14668 |
| August 2023 | 110320 | 135187 | 0.78 | 10613 |
| September 2023 | 122760 | 152024 | 0.77 | 10353 |
| October 2023 | 133460 | 171636 | 0.56 | 20391 |
| November 2023 | 142680 | 191202 | 0.48 | 22643 |
| December 2023 | 152712 | 218885 | 0.37 | 31803 |
| January 2024 | 160356 | 237910 | 0.41 | 19498 |
| February 2024 | 170040 | 257697 | 0.50 | 22503 |
| March 2024 | 179633 | 277328 | 0.50 | 21288 |

Table no.3.6 Observation readings and penalty form July 2023 to March 2024

## III. NECESSITY

APFC (Automatic Power Factor Control) panels are necessary for leading power factor for several reasons:

1. Efficiency: Leading power factor occurs when the load in an electrical system is capacitive, typically caused by equipment such as UPS, transformers, or capacitors themselves. A leading power factor reduces the overall system efficiency and increases losses in the distribution network.
2. Utility Penalties: Many utilities impose penalties for poor power factor. These penalties can significantly increase the electricity bill for industrial and commercial consumers. By maintaining a leading power factor close to unity (1), businesses can avoid these penalties.
3. Voltage Stability: Leading power factor can cause voltage instability in the electrical network, leading to voltage sags and fluctuations. APFC panels help stabilize the voltage by compensating for the leading power factor, thus ensuring a stable supply of electricity.
4. Capacity Optimization: By maintaining a leading power factor, the capacity of the electrical distribution system can be optimized. This means that the system can handle more load without requiring additional infrastructure upgrades, saving costs for the utility and consumers alike.
5. Equipment Protection: Operating at a leading power factor can also help in protecting electrical equipment from damage and premature aging. It reduces the stress on equipment such as transformers and cables, thereby extending their lifespan and reducing maintenance costs

on fossil fuels, the integration of UPS with solar contributes to environmental sustainability by reducing carbon emissions and reliance on non-renewable energy sources.

Solar PV system generates electricity from sunlight, The electricity is used to power the standalone load directly, meeting the immediate electrical demand, Any excess electricity generated but not immediately consumed by the standalone is directed to the storage battery for storage. When the solar PV system is not producing enough electricity to meet the standalone load's demand (e.g., during nighttime or low sunlight periods), the stored energy in the battery is used to supplement the shortfall. The mobile monitoring system allows users to track the systems performance, monitor battery charge levels. The combination of solar PV, storage battery, and mobile monitoring provides a sustainable and reliable source of electricity for standalone loads, reducing dependence on the electrical grid and potentially lowering energy costs.

## IV.RESULT AND DISCUSSION

APFC stands for 'automatic power factor control'. An APFC panel consists of multiple shunt reactors or capacitors of different ratings whose switching can be controlled as per requirement. An APFC is effective as a single-point installation

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which can be used to control the power factor for a large number of loads, instead of installing shunt reactor at the individual locations of each load.

An APFC panel consists of multiple shunt reactors and a controller. These shunt reactors have different ratings. The current from the circuit is sensed and given as input to the controller. The controller identifies how much reactive power is being generated in the circuit and tries to compensate it by switch in shunt reactors on or off.

Depending on the loads in operation, various levels of kVAr compensation are required to maintain proper power factor. The APFC panel contains a multi-step relay which is connected to multiple shunt reactors and a microprocessor controller which is programmed to control the switching operation of the relay. The voltage and current are measured on the feeder which is providing supply to the entire group of loads to determine the uncompensated power factor. Then, as per the ratings of the different shunt reactors used in the APFC and the measured uncompensated power factor, the controller determines which shunt reactors are to be switched on/off to achieve optimal power factor.

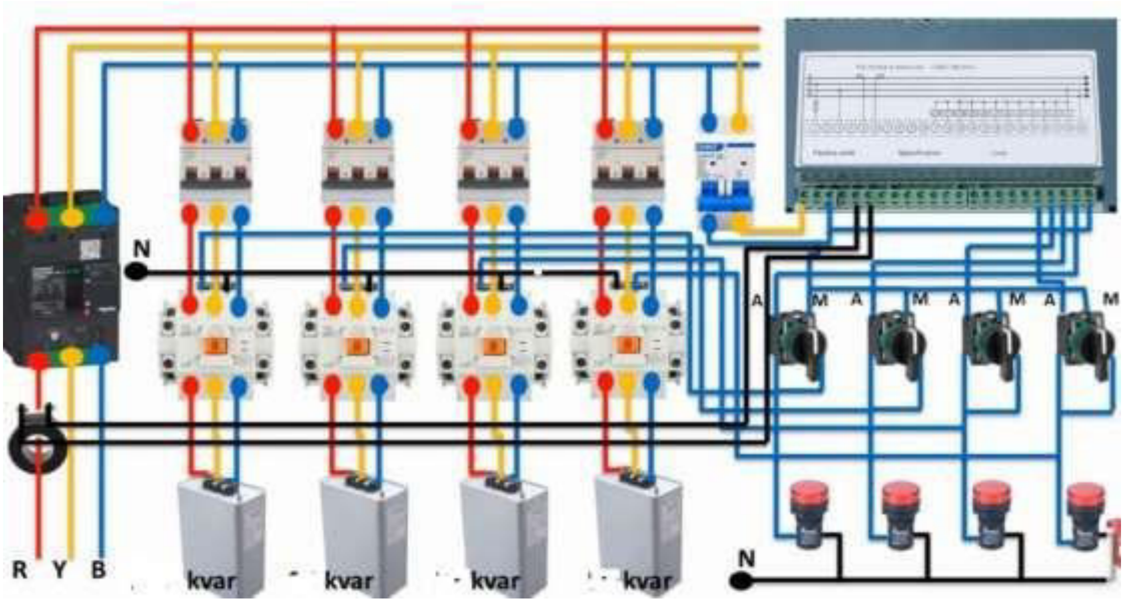


Fig no. 3.2 wiring diagram of APFC Panel Calculations for required capacity of shunt reactor….

Total connected load = 35kw (average) 50 kw (maximum permission) Power factor = Active power/ Apparent power = 8856KWH/19786KVAH Actual power factor=0.44 (leading)
Desired power factor=0.99
Shunt reactor to be calculated =Total connected load*[tan. cos^-1(actual pf) - tan. cos^-1(desired pf)] 50*[tan. cos^-1(0.44) - tan. cos^-1(0.99] 35*[tan. (63.8)-tan. (8.10)] 66.14kvar
But we need compensation of reactive power so, 100-66.14=33.18kvar
Shunt reactor size=42kvar (We are considering extra 9kvar)
Approximate calculations of heat loss in apfc panel (reactor) Shunt reactor capacity = 42 kvar
Average shunt reactor = 31 kvar
Generally, power loss is 15% of total capacity 15% of 31 =4.65 kwh
For 24 hours it will be 24*4.65 =111.6kwh
For 30 days it will be
111.6*30 =3348 units
Cost of per unit is 10 rupees. 3348* 10 = 33480 rupees.
But we get penalty of rupees 20,000
**So a shunt reactor will not be effective in compensating for the leading power factor. ASVG**

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A Static VAR (Volt-Ampere Reactive) Generator (SVG) is a power electronics device that controls the flow of reactive power in electrical power systems. It's also known as an active power factor compensator (APFC) or instantaneous step less reactive power compensator.

SVGs are used to improve energy efficiency and solve power quality problems caused by low power factor and reactive power demand. They can absorb or emit reactive power by adjusting the phase and amplitude of the inverter output voltage. SVGs are connected in parallel with the load that requires harmonics mitigation.

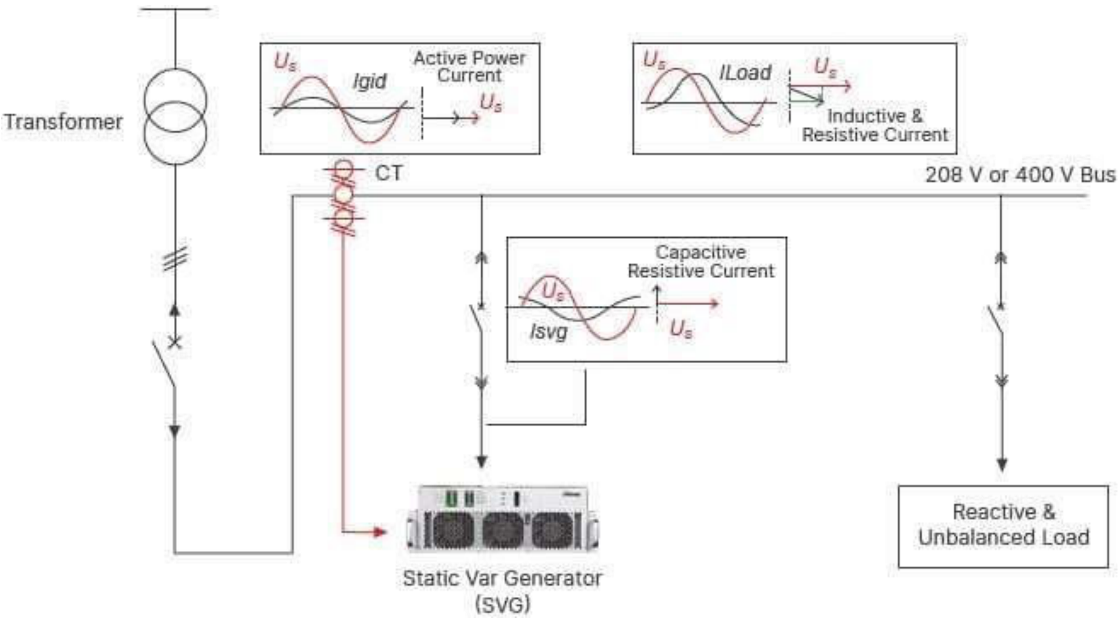


Fig 3.3 SVG diagram

The Static Var Generator, is a reactive power compensation system, used for compensation of normal or dynamic three-phase, balanced or unbalanced loads. The Static Var Generator (SVG) system is composed of a fixed-type Static Var Generator (SVG) module, a door mounted display monitor and a SVG system cabinet. The external CT is used for the detection of load current and extraction of reactive power that needs compensation, based on which, the Static Var Generator (SVG) controller controls the main power circuit to generate reverse reactive current in this way, the load-carrying reactive power is counteracted.

**SVG Principle**
The principle of the SVG is very similar to that of Active Power Filter, as demonstrated in the picture below. When the load is generating inductive or capacitive current, it makes load current lagging or leading the voltage. SVG detects the phase angle difference and generates leading or lagging current into the grid, making the phase angle of current almost the same as that of voltage on the transformer side, which means fundamental power factor is unit.
Here's a detailed step-by-step explanation of how reactive power compensation is achieved in a Static Var Generator (SVG):

**1. Monitoring System Parameters**:
The first step involves continuously monitoring key system parameters such as voltage, current, power factor, and sometimes frequency. These parameters are typically measured using sensors and transducers placed at strategic points in the electrical system.

**2. Control System Initialization:**
The control system of the SVG initializes by receiving input data from the monitoring system. This data includes real-time values of voltage, current, and power factor, which are crucial for determining the reactive power compensation requirements.

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**3. Reference Power Factor Setting:**
The system operator or control algorithm sets a reference power factor value. This value represents the desired power factor that the SVG should maintain in the system. It could be a fixed value or a dynamically changing value based on system conditions.

**4. Calculating Reactive Power Requirements:**
Based on the measured parameters and the reference power factor, the control system calculates the reactive power requirements. This calculation considers the difference between the current power factor and the reference power factor, as well as the system's real and reactive power demands.

**5. Determining SVG Operation Mode:**
The control system determines whether the SVG should operate in capacitive mode (absorbing reactive power) or inductive mode (injecting reactive power) based on the calculated reactive power requirements. This decision is crucial for controlling the output of the SVG.

**1. VSC Control Signals Generation:**
Once the operation mode is determined, the control system generates control signals for the Voltage Source Converter (VSC) components, typically based on Pulse Width Modulation (PWM) techniques. These signals control the amplitude and phase angle of the output voltage from the VSC.

**2. Adjusting VSC Output:**
The VSC adjusts its output voltage based on the control signals received from the control system. In capacitive mode, the VSC reduces the amplitude of the output voltage to absorb reactive power. In inductive mode, it increases the amplitude to inject reactive power.

**3. Dynamic Response and Feedback:**
The control system continuously monitors the system's response to the SVG's output. It receives feedback from sensors and adjusts the control signals as needed to maintain the desired power factor and voltage stability. This feedback loop ensures a dynamic and accurate reactive power compensation process.

**4. Harmonics Control (Optional):**
Some advanced SVGs also incorporate harmonics control features. They modulate the VSC output waveform to mitigate harmonics and improve overall power quality in addition to reactive power compensation.

**5. Integration with SCADA or Supervisory Systems:**
SVGs are often integrated with SCADA (Supervisory Control and Data Acquisition) or supervisory systems. This integration allows for centralized monitoring and control of multiple SVGs in a network, optimizing reactive power compensation across the entire grid.

**Heat loss calculation in ASVG**
Capacity needs to be installed- 50kvar
Generally, power loss is 2.5% of total capacity of ASVG 2.5% of 50 = 1.25Kwh
For 24 hrs it will be 24*1.25= 30kwh
For 30 days it will be v30*30= 900 units
Cost of per unit is 10 rupees So, 900*10= 9000 rupees
We get penalty of approximately 20000 rupees
Yes, ASVG is effective against the compensating leading power factor.

## V. CONCLUSION

As the load is continuously varying with time, we need fully automatic control.
ASVG must be installed to avoid penalty & to mitigate harmonics (due to continuous switching of load) .
Static Var Generators (SVGs) and Automatic Power Factor Control (APFC) panels serve different purposes in power systems. Here are the advantages of SVG over APFC panels.
1. Dynamic Reactive Power Compensation: SVGs can provide dynamic and continuous reactive power compensation, adjusting to rapid changes in load conditions. This dynamic response helps maintain a stable power factor and voltage

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profile in the system, which is not possible with traditional APFC panels that operate in a fixed or step-wise manner.
2. Fast Response Time: SVGs have a very fast response time, typically in milliseconds, making them highly effective in compensating for sudden changes in reactive power demand. APFC panels may have slower response times due to their switching mechanisms and control algorithms.
3. Improved Power Quality: SVGs can improve power quality parameters such as voltage stability, harmonics reduction, and flicker mitigation. They can actively regulate voltage and compensate for harmonic distortions,leading to better overall power quality compared to APFC panels, which primarily address power factor correction.
4. Energy Efficiency: SVGs can contribute to energy savings by optimizing reactive power compensation and reducing losses in the distribution system. Their ability to operate at varying loads and conditions improves overall energy efficiency.

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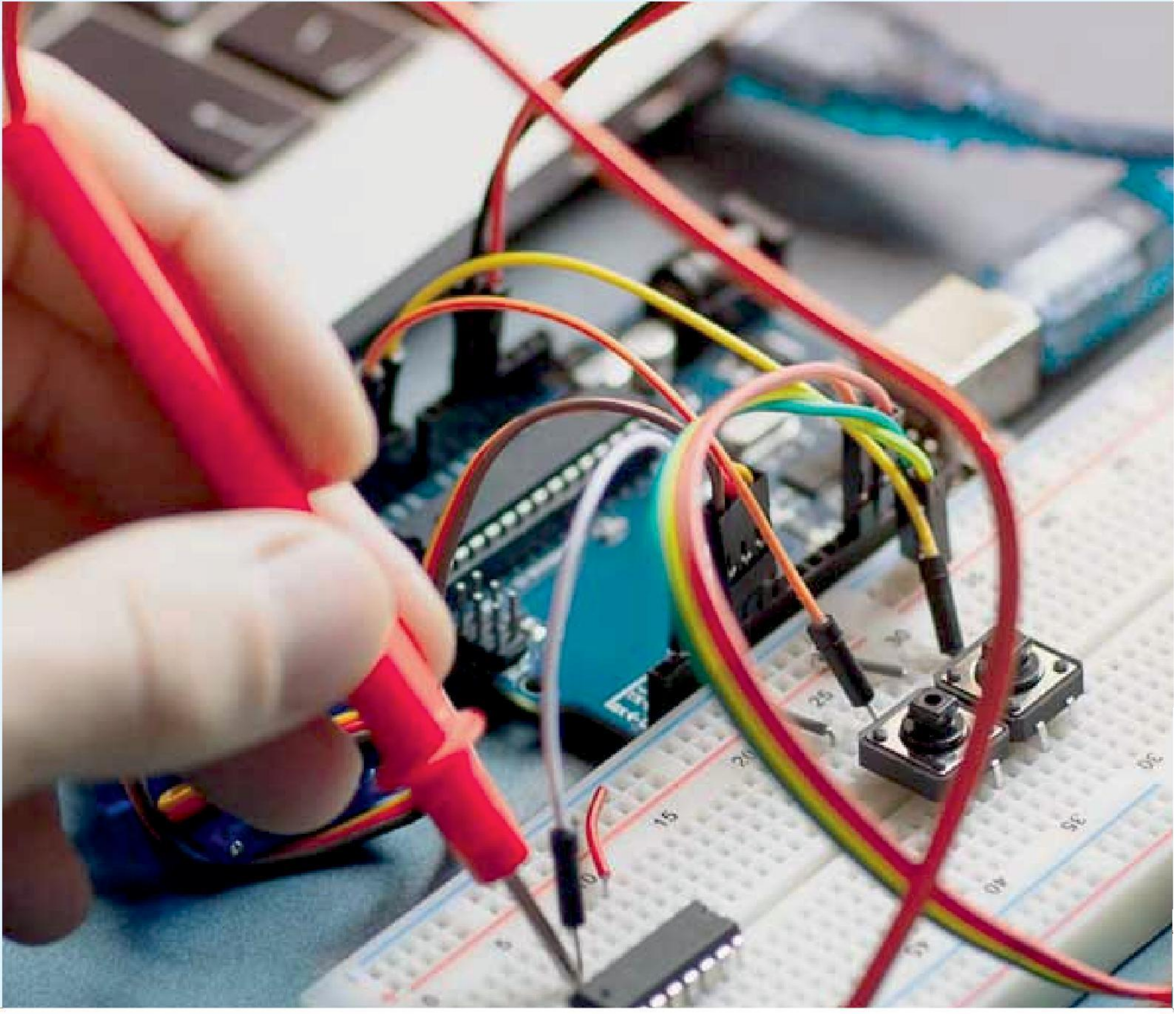

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