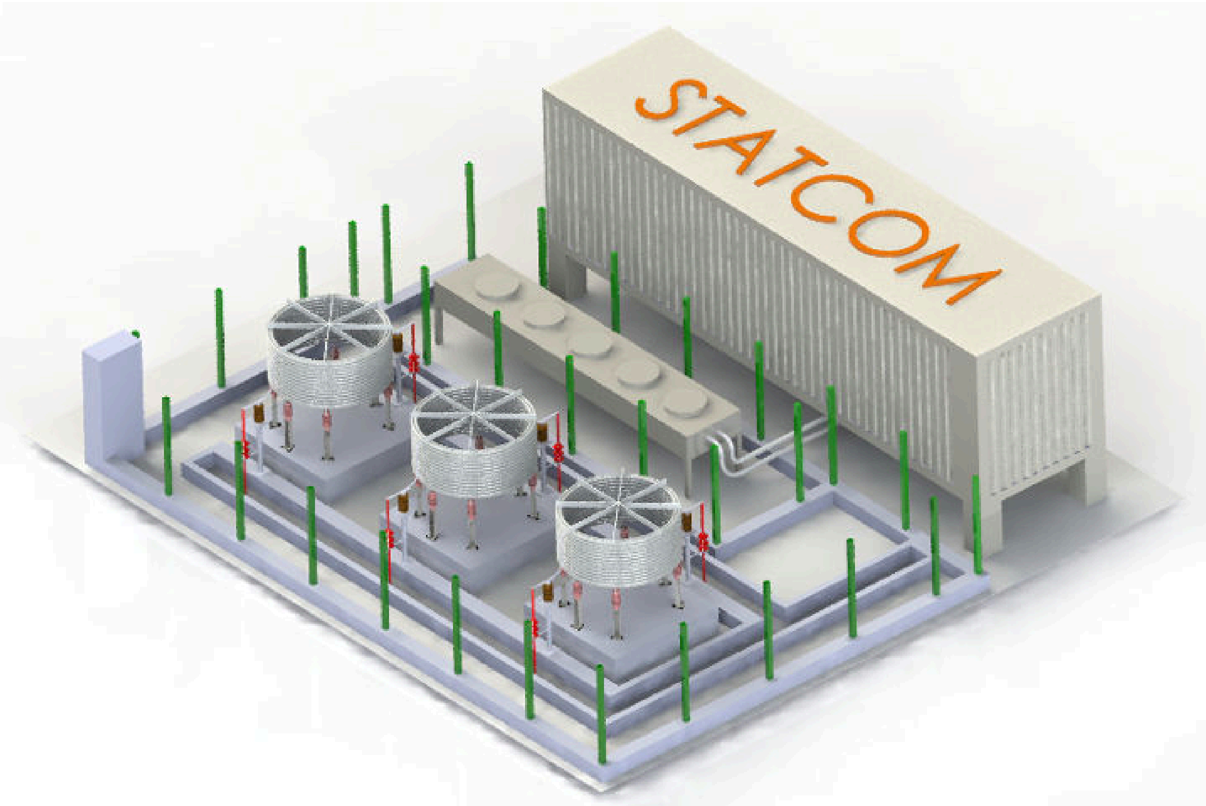
EPRLAB



EPRLAB

Electric Power Research Laboratory, EPRLAB is a high-tech power electronics company that has been specialized on design, manufacturing and implementation of industrial electronic and power systems including Static VAr Compensation (SVC), STATCOM, harmonic filtering and custom design multidisciplinary solutions based on challenging power quality problems.

We utilize our high-tech designs based on continuous research, development and field tests that enables us to achieve highest product reliability while providing innovative solutions for the future leading edge designs.

Serving the power electronics and power quality industry with exceptional expertise and customer satisfaction, EPRLAB continues to be recognized for high-tech engineering, extensive experience, and commitment to excellence.

Keywords of EPRLAB: Power Quality, Renewable Energy, Voltage Regulation, Reactive Power Compensation (RPC), Power Factor Correction (PFC), Flicker Compensation, Harmonic Mitigation, Flexible Alternating Current Transmission System (FACTS).

Products of EPRLAB: Static VAr Compensation (SVC), Static Synchronous Compensator (STATCOM), Multi-level Converter, Voltage Source Converter (VSC), Passive Harmonic Filter (HF), Thyristor Switched Capacitor (TSC), Thyristor Switched Reactor (TSR), Thyristor Controlled Reactor (TCR), RC Snubber, DC Chopper, DC Injection Brake Module, Remote Monitoring and Control System Design.

Services of EPRLAB: Power Quality Analysis, Commissioning, Supervision, Training, Consulting, Engineering, Technical Support, Maintenance.

Please visit http://www.eprlab.com for detailed information on products and solutions.

Send e-mail to info@eprlab.com for any queries, technical questions, and sales information.

Knowledge is POWER

FREQUENTLY ASKED QUESTIONS

Q1) What is power quality?

Power quality is broadly defined as the current, voltage and frequency values staying in the limits defined in standards, for the points in electrical grid where loads are connected. It also includes that the voltage waveform should present a purely sinusoidal shape.

Q2) What are power quality parameters?

- Voltage magnitude
- Frequency
- Reliability and continuity
- Power factor
- Harmonic currents and voltages
- Voltage sags and swells
- Transient events
- Voltage unbalance

Please see *PQ and HF.pdf* for details.

Q3) What are harmonics?

Harmonics are defined as positive integer multiples of the fundamental frequency (50 or 60 Hz) components in both voltage and current waveforms. E.g. 5^{th} harmonic corresponds to a 250 Hz component for a grid having 50 Hz rated frequency.

Q4) What are sources of harmonics?

These are loads which are not linear. Examples are:

- Switch mode power supplies (SMPS)
- Single or three phase rectifiers
- Ac and dc motor drives
- Cyclo-converters
- Office loads (PCs, photocopy machines, printers, etc.)
- Fluorescent lamp ballasts
- Arc, ladle melt, and induction furnaces

Q5) What are the effects of harmonics?

- Overheating in cables, motors, transformers and other switchgear equipment

- False trips in protection equipment
- Blown fuses
- Losses on insulation materials of conductors due to quick aging
- Overloading and bursts in capacitors
- Series and parallel resonance problems in the grid
- Overheating in the neutral conductor

Q6) What are harmonic standards?

In Turkey:

- Bozucu Etki Yaratan Müşterilerin Uymak Zorunda Olduğu Koşullar, TEK, 1992
- Elektrik Sistemi Arz Güvenilirliği ve Kalitesi Yönetmeliği, EPDK, 2004

Worldwide:

- IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems, IEEE Std. 519-1992
- IEC 61000-2-x, 61000-3-x, and 61000-4-x

Q7) How is harmonic filtering made?

The harmonic currents which are formed by nonlinear loads and become a problem for the grid are filtered with different methods to bring their values under the limits defined in standards. The methods include electrical filtering equipment either consisting of R, L, and C only, or also containing semiconductor switches such as IGBTs and MOSFETs. Please see *PQ and HF.pdf* for details.

Q8) What are harmonic filter types?

- Passive filters
  - 1st order (e.g. Single-tuned)
  - 2nd order
  - 3rd order
- Active filters
- Hybrid filters

Q9) How does parallel resonance problem occur?

The passive harmonic filters connected to the grid go into parallel resonance with the impedance of the grid itself at a specified frequency. This means that the parallel impedance of the passive filter and the grid becomes a very high value at the parallel resonance frequency. If there is a harmonic source near this frequency, very high voltages and currents at this frequency occurs which causes damage to equipment. This phenomenon is defined as the parallel resonance problem.

Q10) What are interharmonics?

Interharmonics are defined as positive non-integer multiples of the fundamental frequency (50 or 60 Hz) of both current and voltage waveforms. E.g., it is possible to define an 89 Hz interharmonic which corresponds to 1.78^{th} interharmonic for a grid having 50 Hz as the fundamental frequency. Interharmonic currents are produced by some special loads.

Q11) What is flicker?

Flicker is basically defined as the pulsation in the lighting magnitude with a defined frequency which causes discomfort to human eye. This happens because the changes in voltage magnitude affects the intensity of light directly. The most disturbing frequency of flicker is in the 5 to 15 Hz interval.

Q12) What is reactive power?

The energy which does not turn into work, but is stored in electric and/or magnetic field is called reactive energy. The amount of this energy in unit time is called reactive power and it is represented in Volt-Amper reactive (VAr).

Q13) What is power triangle?

The right triangle formed by active (real) power, reactive power and the square root of the sum of squares of these two (apparent power) is called the power triangle.

Q14) What is power factor?

The ratio of active power (P) to apparent power (S) is called the power factor. It is defined as the cosine of angle which is between S and P in the power triangle. The power factor gets values from 0 to 1 for inductive loads, whereas it is between 0 and -1 for capacitive loads.

Q15) What are reactive power limits?

As per regulations that are valid in Turkey, in industrial areas, the ratio of reactive energy to active energy should not be above 20% for inductive region, and 15% for capacitive region, for a specified period of time. The period may be a total month down to a day, depending of the type and rated power of the customer. If these limits are violated, the customer is bound to pay a reactive energy penalty. Although the ratios may vary, most of the countries worldwide apply similar measures to discourage consumption of reactive power.

Q16) What are power factor limits?

The maximum ratio of reactive power to active power is defined in related regulations. For Turkey, when calculations are made by using the ratios given in the answer of Q15, it turns out that the power factor should be higher than 0.98 in inductive region, and 0.989 in capacitive region.

Q17) What is reactive power compensation (RPC)?

It is not necessary for the reactive power consumed by the loads to be produced in the power plants. This power can be produced right at the place where it is needed, by using correct equipment in series or parallel with the load. In other words, if a correctly rated capacitive load is connected in parallel with an inductive load, the reactive power will flow only through these two, and it will not be reflected to the grid. Similar is true when the load is capacitive and the compensator is inductive. The two loads will compensate for each other's reactive power. This is called reactive power compensation (RPC).

Q18) In which situations should RPC be made?

RPC should be made when the power factor is out of the limits defined by the related regulations. Apart from this, it can be made without the main aim being correcting the power factor, since it also regulates the bus voltage. One more benefit of RPC is that, since the apparent power (and the current magnitude) is reduced by reducing the reactive power drawn from the grid, I^2R losses during the transmission and distribution stages will be reduced.

Q19) Is RPC achieved only with parallel capacitors?

RPC is achieved mainly by connecting a compensator with the reverse sign of reactive power of load, in parallel with it. Since most of the industrial loads are inductive, RPC is usually made by connecting parallel capacitors (or harmonic filters). However, RPC is not limited with passive circuit elements only. Synchronous condensers, STATCOMs and active filters may also be used as compensators. These mainly act as voltage sources. On the other hand, passive circuit components can be controlled to have variable reactive power with the help of semiconductors as in Thyristor Controlled Reactor (TCR), Thyristor Switched Capacitor (TSC), and etc. Moreover, RPC is not only achieved by parallel connection of compensator. A series compensation in the lines can also be made. Thyristor switched series capacitor (TSSC) is an example to this. Please refer to *RPC and FACTS.pdf* for details.

None of these devices should be overrated, since it may cause the power factor to go below the limit in the other quadrant of P-Q curve, which means paying reactive energy penalty again.

Q20) Should RPC made separately for every load?

RPC being made as closest as possible to the point where reactive power needed is the best solution, theoretically. However, this may not be an optimum solution in practice. In industry, there may be more than one distribution or step-down transformer fed from distribution voltage around 34.5 kV, for a single factory or foundation. For such cases, if the loads are not very far from each other, it may be better to compensate from the secondary sides (0.4 kV-6.6 kV for example) of each transformer for the total load. However, in some cases the lines going from the transformer secondary to separate loads may cover a long range. For these, it may be better to compensate each load individually in order to decrease losses and voltage drops in the cables. If the aim is to avoid any reactive energy penalty only, then RPC can be made only at the MV side, where the energy meter is connected.

Q21) What are the most common RPC techniques?

- Conventional compensation with shunt capacitors (may be switched with contactors or breakers)
- Harmonic Filter, HF (tuned or detuned)
- Thyristor Switched Capacitor, TSC (with plain capacitors or HFs)
- Thyristor Controlled Reactor, TCR
- Thyristor Switched Reactor, TSR
- Static VAr Compensator, SVC (a combination of HFs, TCRs and TSCs)
- Synchronous Condenser (An unloaded synchronous generator)
- Static Synchronous Compensator, STATCOM
- Active Power Filter, APF
- Series Capacitor (connected in series with the line to decrease the effective line reactance)
- Thyristor Switched Series Capacitor, TSSC

Please refer to *PQ and HF.pdf* and *RPC and FACTS.pdf* for details.

Q22) What are the most commonly made mistakes in RPC?

- Using plain capacitors compensation banks instead of detuned or tuned HFs
- Choosing the rated voltage of compensation capacitors, equal to grid rated voltage
- Careless selection of tuning frequencies for detuned and tuned HFs, no study made on impedance vs frequency characteristics of the total system
- Assuming the rated power of the capacitor bank to be provided when connected to the grid plainly or in HFs
- Implementing slow compensators such as mechanically switched HFs for a fast load requiring SVC or STATCOM

Q23) What does FACTS mean?

FACTS is the abbreviation for Flexible Alternative Current Transmission Systems. It is used for the systems that enhances reliability, stability, capacity and power quality and reduces power losses of electricity network.

Q24) What are FACTS devices?

FACTS devices can be classified into four groups as a) shunt compensation, b) series compensation, c) combined compensation, and d) high voltage dc transmission.

a) Shunt compensation

- Thyristor Switched Capacitor, TSC
- Thyristor Switched Reactor, TSR
- Thyristor Controlled Reactor, TCR
- Static VAr Compensator, SVC
- Static Synchronous Compensator, STATCOM
- Active Power Filter, APF

b) Series compensation

- Thyristor Switched Series Capacitor, TSSC
- Thyristor Controlled Series Capacitor, TCSC
- Gate Turnoff Thyristor (GTO) Controlled Series Capacitor, GCSC
- Static Synchronous Series Compensator, SSSC
- Dynamic Voltage Restorer, DVR
- Phase Angle Regulator, PAR

c) Combined compensation

- Unified Power Flow Controller, UPFC
- Interline Power Flow Controller, IPFC

d) HVDC transmission

- Line Commutated Converter, LCC
- VSC Based (MMC)

Except for TSSC, the series and combined compensation FACTS devices are not commonly used. The most commonly used FACTS devices are of shunt type, such as SVC and STATCOM. As can be seen in the answer of Q21, most of the FACTS devices are used as RPC systems. Please refer to *RPC and FACTS.pdf* for details.

Q26) Who is EPRLAB?

Electric Power Research Laboratory, EPRLAB is a company devoted to electrical power research and providing reliable power solutions to its customers. Accordingly, it provides turn-key solutions as well as supervision and consulting on LV and MV RPC and FACTS devices such as Harmonic Filters, SVCs, STATCOMs, etc. The company continuously carries on its R&D studies with the excitement of providing new products and solutions to its customers.