The EQUALIZER

Real-time power quality enhancement system: Power factor correction, energy savings, voltage support, flicker reduction, current spike reduction, harmonic filtration and many other applications for a variety of dynamic loads.

ELSPEC

- Complete compensation in $^2/_3$ cycle typical
- Energy savings
- Significantly reduce voltage drops & flickering
- Harmonic filtration
- Transient-free switching
- Improve service utilization
- Enhance local power generation capacity

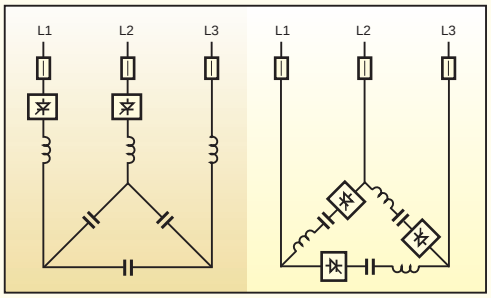
Power Quality Solutions

elspec-ltd.com

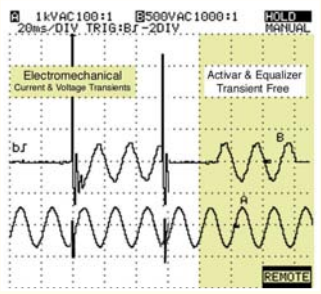
EQUALIZER Technology

Capacitor Group Switching

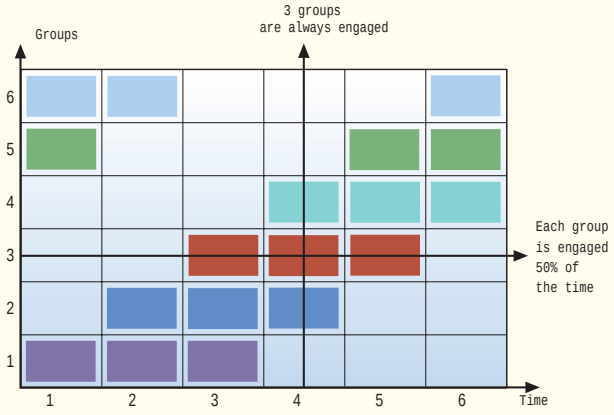
The EQUALIZER switches capacitor groups on and off using state-of-the-art electronic switches. The connection and disconnection of capacitors occur precisely at zero-current crossing. This smooth connection avoids transient effects typically created by electromechanically switched power factor correction (PFC) systems, extending the life expectancy of the EQUALIZER dramatically.



2- and 3-Phase Switching Structure



Electromechanical vs. Transient-free Switching



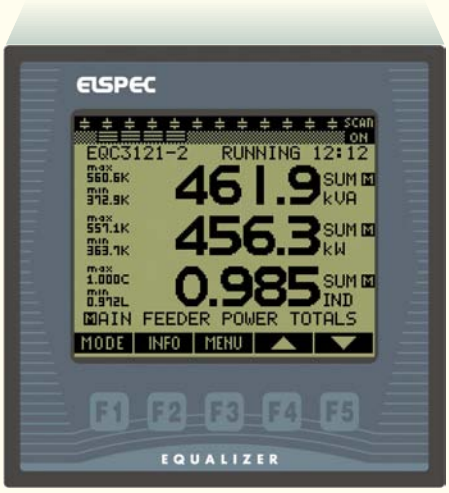
SCAN Mode

SCAN Mode

The EQUALIZER is equipped with a unique SCAN feature that protects capacitors from exploding and contributes to longer life expectancy by reducing over-current and minimizing capacitor heating. The electronic switching element (unlimited operations) connects one capacitor group simultaneously as another group is disconnected. This operation occurs every few seconds, engaging each capacitor group in turn, with total compensation unchanged. This results in mean current reduction due to lower duty cycle (engagement time to cycle time). Together with the unique reactor design, temperature rise of the reactors is substantially reduced and the potential for cabinet overheating is minimized.

Consistent Capacity

Conventional electromechanical capacitor banks suffer from an ongoing cumulative reduction in capacity due to the effect of transients during connection and disconnection. This can be especially detrimental in tuned and detuned electromechanically switched systems where changes in the ratio between the capacitors and reactors shift the resonant frequency. This scenario can cause resonance, which can cause extreme damage to equipment in the facility. The EQUALIZER prevents this scenario, resulting in longer system life, lower maintenance costs and more consistent harmonic filtration over time.



The Controller

Ideal PFC Control

Using exclusive automatic control algorithms and rapid electronic switching, total acquisition time (complete compensation of reactive current) is achieved in $^2/_3$ cycle typical (50Hz = 13.3 ms; 60Hz = 11.1 ms), irrespective of the number of steps required.

The power factor is controlled very accurately through an advanced open and closed-loop control & measuring system that uses information from all three phases, as well as accounts for the effect of harmonics (1 through 63). Minimum, maximum and average power factor modes, as well as threshold levels, can be selected for perfect compliance with specific network requirements. The EQUALIZER includes a unique solution for line-to-line loads, in which it calculates a transformer's internal currents and compensates accordingly. Third party measurements have proven the EQUALIZER to be the ultimate solution to offer precise compensation for voltage drop and flickering.

Fast and Accurate Measurements

The EQUALIZER controller uses FFT (Fast Fourier Transform) analysis of all phases each cycle. Power information, system status and detailed logs of events are displayed on a large backlit graphic LCD screen, or via communication using the user-friendly PowerIQ software.

PowerIQ Measurement & Analysis Software (optional)

This Windows-based software can display the system's status, measurement results and real-time data.

1 Group Switching Module

The EQUALIZER Power Quality Solution

Definition

Power Quality is a term used to define any occurrence of voltage, current or frequency deviation that results in equipment failure, process interruptions or power system inefficiency. These deviations can manifest themselves in harmonics, power factor, voltage sags/swells, voltage flickering, transients and many other forms. The EQUALIZER from Elspec is an all-in-one solution for power quality problems, typically installed near the main service and near major distribution panels.

Voltage Sags (Voltage Drops, Under-Voltage)

Voltage sags, also known as voltage drops or under-voltage, are caused by local loads, either during motor startup or from rapidly changing loads. This condition is characterized by low power factor and high reactive energy demand. The Elspec EQUALIZER's ultra-fast technology is designed to act in these specialized conditions. It connects all required capacitor banks in $^2/_3$ cycle typical, compensating for the total reactive energy of the event. Moreover, it changes the direction of the voltage drop vector to minimize the sag. As a result, the voltage sag is minimized and in many cases, even eliminated (See Motor Startup and Elevator application notes on next page).

Voltage Flickering

Voltage flickering is caused by fast voltage fluctuations commonly associated with rapid loads, such as spot welders. The EQUALIZER's control technology connects and disconnects all required capacitor banks in $^2/_3$ cycle typical, effectively reducing the flicker to acceptable levels (See Spot Welding application note).

Power Factor

In many cases, low power factors result in higher utility bills through penalties and increased demand charges. They also cause system energy losses, overheating, increased maintenance costs and low service utilization. The Elspec EQUALIZER is the foremost solution for low power factor, preventing utility penalties, saving energy, reducing maintenance costs and increasing service utilization.

Harmonics (non-linear loads)

High harmonic voltages and currents cause significant energy losses, overheating and dramatically increase site vulnerability to failures and fire. More details on harmonics appear under the applications section on next page.

Spikes (Transients)

Spikes (transients) can cause significant damage to equipment, produce unpredicted power supply failures and degrade capacitors. The EQUALIZER solution uses transient-free switching technology to eliminate all spikes associated with conventional capacitor switching. The results are longer capacitor life expectancy, less maintenance costs and higher network reliability.

Service Utilization

Higher service utilization is a constant wish of all electricity users, whether the power is provided by the utility, generators or other local generation such as wind turbines. Employing the EQUALIZER may dramatically increase the existing service utilization by reducing the average current and stabilizing current fluctuations. Existing installations show service utilization increases of up to 60% (See Generator application note).

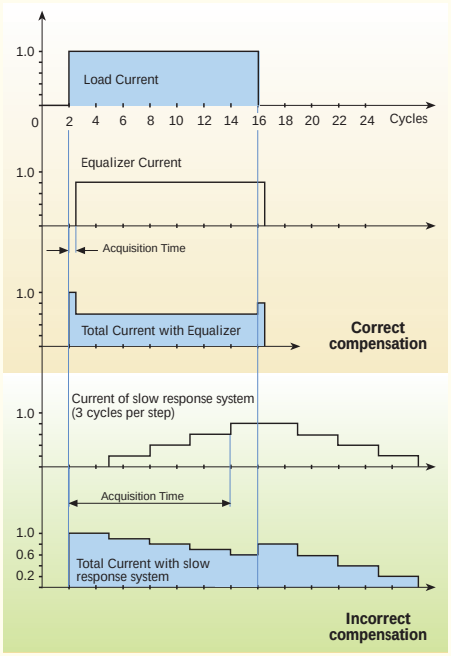
Voltage Control

In addition to power factor and other power quality issues, at times there is a need to maintain voltage levels within certain limits due to sensitive equipment or other facility requirements. The EQUALIZER voltage control option offers 6 different voltage control levels that facilitate both high and low parameters. The voltage control operates in parallel with the power factor control and complements it.

Power Factor Compensation – A Comparison

The EQUALIZER is an ideal solution for power quality applications. Regardless of the application, the EQUALIZER solution achieves near-perfect power factor control, network stabilization and energy savings.

In many cases, the EQUALIZER is the only proper solution. Implementing slow-response power factor compensation or even quasi-real-time systems in these applications would actually reduce power quality and possibly produce wasted energy. The following example compares the results of the EQUALIZER (unlimited steps, $^2/_3$ cycle typical) with a quasi-real-time solution (1 step, 3 cycles):



Correct compensation using the Equalizer

The top graphs demonstrate the EQUALIZER's compensation of the reactive current in a 14-cycle energy load. Typical acquisition time (full compensation of reactive current) is $^2/_3$ cycle typical and total current is substantially reduced.

Adverse effects of slower response systems

The bottom graphs demonstrate incorrect compensation where response time is 3 cycles to connect a single group and acquisition time required to connect a total of 4 groups is 12 cycles. Due to the delay in connections, the current is only partially reduced. Further, the corresponding delay in disconnection causes residual current. The overall effect of this compensation system on total current is negative, as the average current of the load is increased, rather than decreased. This phenomena will increase voltage flickering due to overcompensation.

Power Quality Solutions

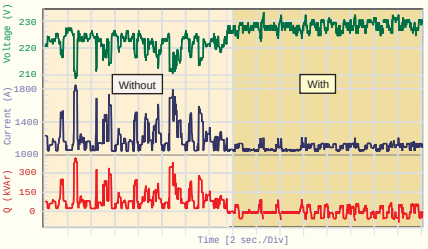
Applications

Welding Machines

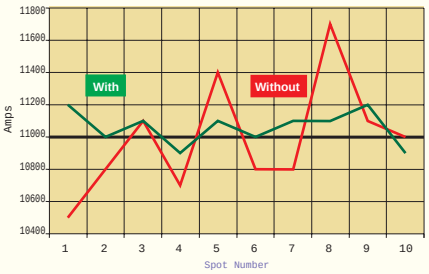
Spot welding loads fluctuate extremely rapidly and consume large amounts of reactive power. Due to high current changes caused by the near-instantaneous reactive energy consumption, large voltage drops are produced. These sags reduce weld quality and decrease welding productivity. Additionally, these loads often create a high incidence of voltage flickering, which frequently exceeds recommended IEEE limits. Elspec's real-time EQUALIZER benefits:

- Improved weld quality and reduced scrap/rework
- Increased process output
- Reduced voltage flickering
- Enhanced service utilization for the facility (better utilization of the existing power infrastructure)
- Reduced maintenance costs

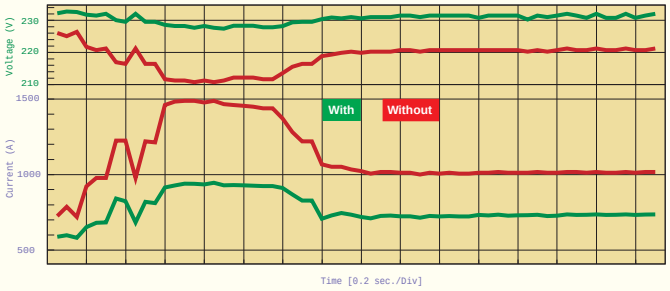
The top graph on the right demonstrates how the EQUALIZER prevents voltage drop and flickering, substantially reduces the current and fully compensates reactive energy requirements. The bottom graph on the right illustrates welder tips DC current with and without the EQUALIZER solution. Optimal welding conditions require a stable current at the weld tips. In this example, current variations are reduced by 75% with the EQUALIZER solution (±200A vs. ±800A).



Spot Welding - Car Industry



DC Current at Welder Tip



AC Motor Startup

Plastic Injection Molding

Due to widely varying unsynchronized load conditions, plastic injection molding applications have rapid & inconsistent reactive energy requirements. Power supply failure during a production cycle can cause enormous financial and physical damage caused by plastic cooling inside the machines. Besides reducing overall system energy losses, Elspec's EQUALIZER solution drastically reduces the risk for such an event by stabilizing the current and voltage levels in the facility on a cycle-by-cycle basis.

Motor Start-up

When connected directly to the line, large squirrel-case inductive motors consume very high current during the start-up period (six times higher than steady state operation). This high current consumption can lead to significant voltage drops on both the low and high voltage sides of the transformer, which interfere with other loads, reduce initial torque and increase start-up time. The EQUALIZER system tracks the reactive current and fully compensates it in $^2/_3$ cycle typical, offering the following benefits:

- Protection against voltage drop on the main service
- Capability to central-start all loads, avoiding the use of individual starters commonly used to protect against voltage drop
- Direct connection of motors to main service, obtaining maximum torque during start-ups. This benefit is unique to the EQUALIZER solution, as starters of all types typically reduce the current going through the motor, thereby reducing the starting torque.

Harbor Cranes

The complete operation cycle of harbor cranes is approximately one minute. During this time, the crane requires variable amounts of reactive energy, fluctuating rapidly throughout the entire crane cycle.

The Elspec EQUALIZER's real-time solution:

- Stabilizes the voltage
- Reduces the current
- Allows installation of a smaller service (less cable, less heat)
- Lowers system losses
- Saves energy

Applications (cont.)

Harmonics Filtration

Harmonics pollution increasingly becomes a dominant power quality problem, mainly due to modern loads. Coping with this issue using capacitor bank has two alternatives:

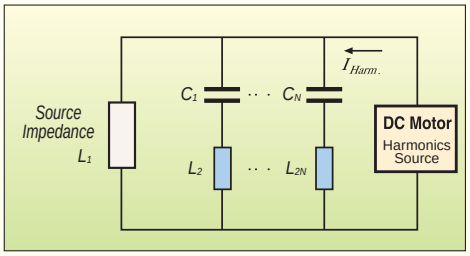
De-tuned Systems

In de-tuned systems, reactors are installed in series with the capacitors and prevent resonance conditions by shifting the capacitor/network resonance frequency below the first dominant harmonic (usually the 5th). The middle graph on the right shows the capacitor/network amplification factor and the shifting of the resonance frequency from near the 5th harmony to near the 3rd harmony.

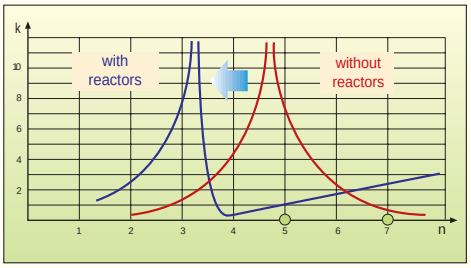
Tuned Systems

If harmonic filtration is needed, on top of resonance prevention, tuned reactors are applied. The capacitor/reactor filter is tuned to absorb particular harmonics and reduce the Total Harmonic Distortion (THD). The bottom graph on the right shows harmonic filtration using tuned system: the voltage THD was reduced by more than 70% (8.8% to 2.5%) and the dominant harmonics (5th and 11th) were reduced by 75%.

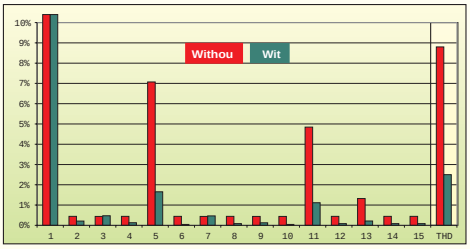
Tuned Equalizer vs. Active Harmonic Filters: Active filters inject currents to the network in anti-phase to the harmonics. This technology is an expensive solution, and increases system losses (3% typical). For applications with one or two dominant harmonics, Elspec's tuned Equalizer is the preferred choice, both technically and economically, effectively minimizing system losses and reducing the Total Harmonic Distortion (THD).



Harmonic Polluted Network



Shifting resonance frequency below the 5th harmonic



Voltage Harmonic Filtration Example

Electric Trains

Electric rail lines have long power distribution systems and rapid load changes, leading to substantial voltage drops and voltage flickering. The Elspec EQUALIZER system:

- Provides voltage support to the distribution network
- Stabilizes network power
- Prevents low power factor penalties
- Minimizes system losses and maintenance costs
- Increases network loading capabilities

Hospitals, High-rises and Other Commercial Buildings (elevators, air conditioning, critical loads)

Most commercial buildings have significant load variations caused by elevators, air conditioninig equipment and other rapidly changing loads. Further, today's medical equipment, computers and other sensitive loads can be damaged by spikes caused by conventional capacitor systems. The EQUALIZER:

- Stabilizes the facility load
- Eliminates spikes caused by capacitor switching
- Increases life expectancy of sensitive equipment
- Reduces maintenance costs
- Increases available power for new loads on existing infrastructure

Generators (emergency stand-by, parallel and stand-alone operation)

Use of generators for local power generation for normal facility operations and emergency back-up have become much more prevalent in recent years. All types of generators can benefit from power factor compensation provided by the EQUALIZER. Further, the EQUALIZER is the only power factor correction equipment approved for connection by generator manufacturers.

The Elspec Equalizer:

- Increases useable power
- Allows separate target power factor programming, dependent on generator operational mode, when specified with generator option
- Potentially increases financial savings when multiple generator systems are used in tandem
- Enables downsizing of new generator installations

Wind Energy

Wind turbine generators have become a significant contributor to power generation throughout the world. As a result, utility regulations for wind turbines have become more constrained, and now require stable voltage, reactive energy supply to the network and voltage control to support network failures. The Elspec EQUALIZER-W is specifically engineered for the wind energy market, and features communication protocols that match its controller to the algorithms of leading wind turbine manufacturers worldwide.

Other Industrial Loads

The Elspec EQUALIZER is successfully installed in thousands of sites with other applications that due to space limitation were not described in this catalog. The EQUALIZER can benefit all users, regardless of their specific application, to save energy, improve power quality, filter harmonics, prevent voltage drops and much more.

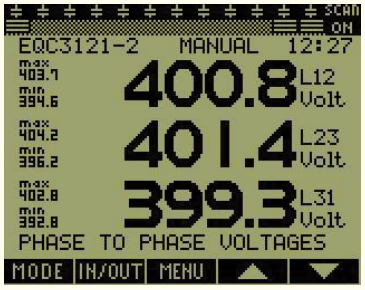
Power Quality Solutions

The Controller

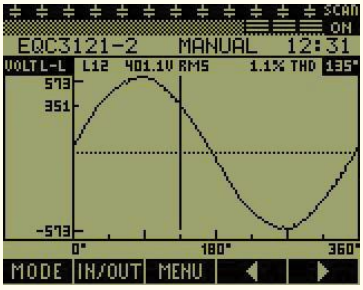
A digital signal processor (DSP) and a VLSI component form the basis of the controller's technology. It features an LCD display, analog and digital circuitry, precise firing algorithms and optional communication capabilities. The controller has 9 input channels: 4 voltages (for Wye networks), 3 main currents and 2 internal system currents. The information obtained from these measurements is used for Fast Fourier Transform (FFT) analysis, performed each network cycle on all channels. The advanced control algorithm, which includes unique patent-pending technology for fast compensation, calculates the required compensation in 1ms. Further, harmonics are calculated on all phases, allowing the EQUALIZER to achieve ideal compensation even in the presence of harmonics.

The EQUALIZER's controller is available with a choice of data gathering levels, from essential power parameter measurements only (V, I, f, kW, kVA, kVAr) to complete power system performance monitoring that takes advantage of the comprehensive measurement system (over 2,000 electrical parameters, including min/max levels and four-quadrant measurement of power and power factor).

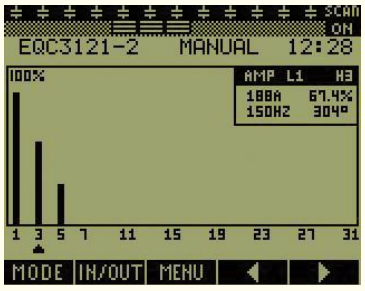
The large LCD display is full-graphic, 160x128 pixels, and has long-lasting LED backlighting with FSTN technology. Characters are displayed in varying sizes and methods to enhance visibility. These include a Large Digits display, Harmonic spectrums, real-time Waveform plots and simple Text screens that include menus, easy-to-use setup programs and various measurements.



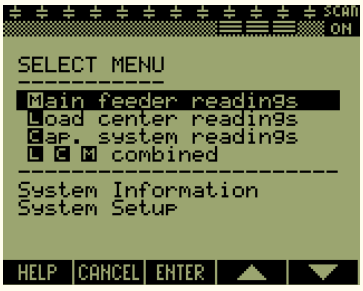
Digits Display



Waveform Display



Harmonic Bar Display



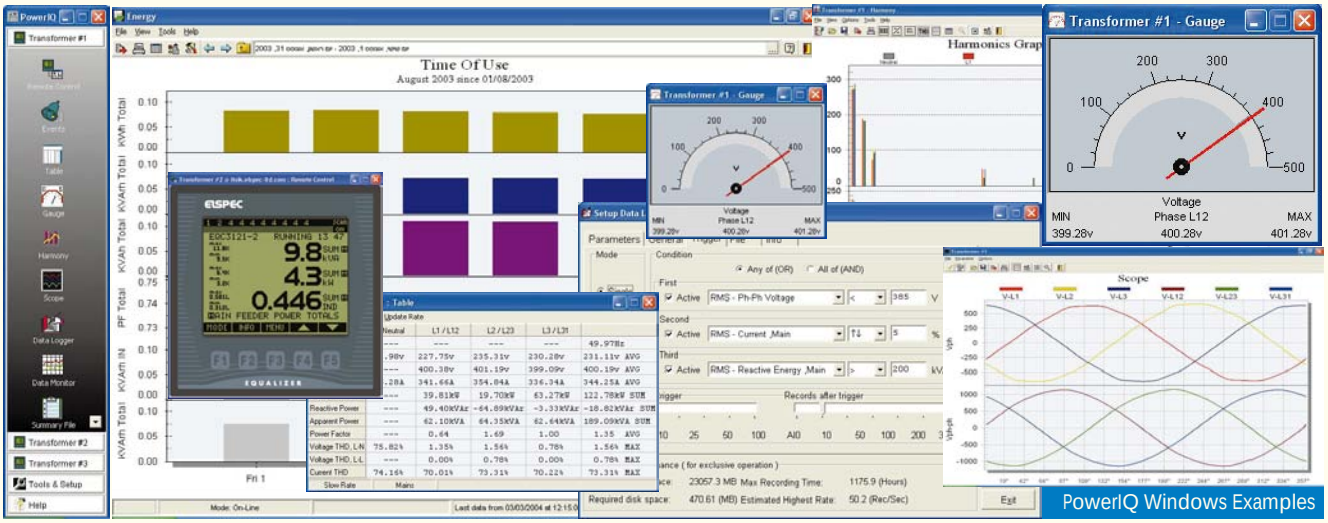
Text Display

The Equalizer controller is available with several configuration options (see ordering information on back page of catalog):

U - Unbalanced system for three-phase networks with single-phase capacitors
S - Single phase system for single-phase networks with single-phase capacitors
W - Wind Energy, a version specifically designed for wind turbine generator applications
V - Voltage Control, where the controller connects or disconnects steps according to user-defined voltage limits (6-level)
T - Medium Voltage compensation, using LV capacitors and step-down transformer
M - Medium Voltage compensation, using MV capacitors (see Type T)
G - Generator applications, allows two power factor targets dependent on generator mode of operation
P - External trigger signal for synchronized compensation, allowing instantaneous compensation (0ms)

PowerIQ - Measurement & Analysis Software

This optional proprietary software works in parallel with the on-board controller, displaying system status and measurement results in a Windows operating environment, and allows the user remote-access to control various parameters of EQUALIZER system. All network parameters, including harmonics, can be recorded continually or for pre-selected intervals. Recording time is limited only by the size of the computer's hard disk or other storage device (server, memory card, etc). Electrical events can be captured by associating trigger values to various network power parameters, such as low voltage or high current. The event recording will capture a user-selected before and after window of time. PowerIQ has intranet and internet support capabilities.



PowerIQ Windows Examples

System Structure

Switching Module

The switching module is comprised of solid-state switching elements that provide reliable, high-speed, transient-free operation. Single, double or three-phase electronic switches, SCR/SCR or SCR/diode, are used for each capacitor group. Switching modules are specifically selected for each EQUALIZER system based on the number of overall capacitor groups, current requirements and voltage ratings.

1 Group Switching Module System Structure

Cabinet Design

Each EQUALIZER system IP20/NEMA1 cabinet is made of steel sheet, which is epoxy powder coated gray (RAL 7032).

Cabinet Options

- Protection class upgrades (IP/NEMA)
- Top-mounted fan unit and filters
- Lockable controller panel
- Blown fuse indication
- Magnetic door lock
- Top cable supports
- Lifting eye bolts
- Pad-lock entry

Capacitor/Reactor Modules

Iron Core Reactors

Each Elspec EQUALIZER includes specially designed, iron core reactors used in series with the capacitors. Each reactor is manufactured under tight control tolerances to ensure quality, constructed with a laminated, low-hysterisis loss iron core, copper windings, precision-controlled air gaps and Class H insulation (180^{0}C).

Available reactor types:

Inrush-only: Reactors designed to limit the inrush current which may develop in the capacitors during power up, avoiding damage to switching elements, fuses and capacitors

De-tuned: Prevent resonance conditions by shifting the capacitor/network resonant frequency to below the first dominant harmonic (usually the 5th)

Tuned: Designed to absorb a majority of the dominant harmonic(s), usually the 5th and/or 7th.

Capacitors

Elspec EQUALIZER features MKP-type capacitors that are low-loss (0.25W/kVAr) and housed in cylindrical aluminum casings. The MKP-type capacitor is a metallized polypropylene film capacitor featuring self-healing properties and an overpressure tear-off fuse. To reduce the effects of electrical and thermal overload and extend operating life expectancy, the capacitors are connected during zero-current crossing and operated in a time-sharing mode (SCAN).

Specifications

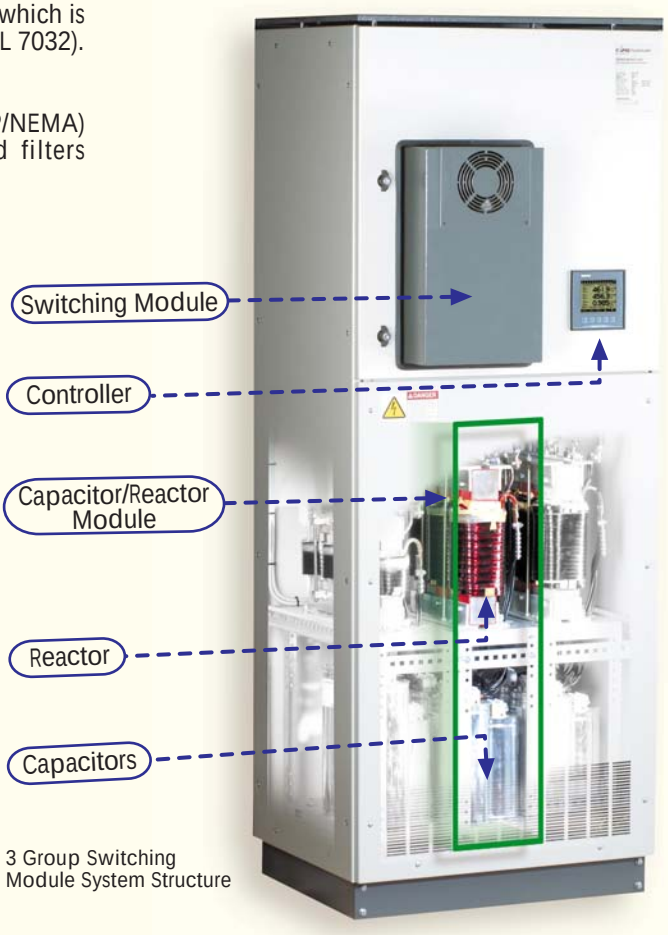
Rated Voltage:
Low voltage systems:
220 V - 690 V
50 or 60 Hz
Single phase or three-phase

Medium voltage systems:
up to 69 kV
50 or 60Hz

Ambient Temperature Limits:
+ 40^{0}C: max (< 8 hours)
+ 35^{0}C: max 24 hr average
+ 20^{0}C: yearly average
- 10^{0}C: minimum

Capacitors:
Low loss, self healing, IEC 831-1/2

Protection class:
IP 20 / NEMA 1 (Other on request)



3 Group Switching Module System Structure

Controller Display:
5" Graphic LCD
160*128 pixels
High visibility (FSTN)
Durable LED Backlight

Design:
Steel sheet cabinet

Enclosure Finish:
Epoxy powder coated
Gray (RAL 7032)

Internal parts:
Rust-proof

EMC Standards:
EN 50081-2
EN 50082-2
EN 55011,
EN 61000-4-2/3/4/5
ENV 50204
ENV 50141

Safety Standards:
EN 61010-1
EN 60439-1
UL 508 (on request)

ELSPEC

Power Quality Solutions

Power Quality Solutions

Complete System Ordering Information

System Type	Total Power		Step Size		No. of Groups		Nominal Voltage		Nominal Frequency		Reactors Percentage		Network Typology	Group Protection	Cable Connection	Cable Entry
EQ	1440	:	120	:	12	-	400	-	50	-	P7	-	W	F	C	A

System Type	EQ	Equalizer Complete System
Total Power		Total power in kVAr
Step Size		Step size in kVAr (Switching Resolution)
No. of Groups		Number of Groups (Physical, max. 12)
Nominal Voltage		Nominal Phase-to-Phase Voltage in Volts
Nominal Frequency		Nominal Frequency in Hz (50 or 60 Hz)
Reactors Percentage	P0	Inrush Limiting Reactors Only
	P#	Percents of Capacity. Example: P7 = 7%.
Network Typology	D	Delta 3 wires
	W	Wye 4 wires
	V	Wye 3 wires
	S	Single phase
Group Protection	F	Groups protected by Fuses
	M	Groups protected by MCCBs
Cable Connection	C	Single Point with Integral Circuit Breaker
	S	Single Connection Point
	M	Multiple Connection Points
Cable Entry	T	Top Cable Entry
	B	Bottom Cable Entry
	A	Top and Bottom Cable Entry
	L	Left-side Cable Entry
	R	Right-side Cable Entry

Example:
EQ 300:60:3-400.50-P7-WFSA
300kVAr real-time complete Equalizer system with 5 steps of 60 kVAr with 7% inductors, for 400V/50Hz 4-wires Wye network.
Dimensions (W*D*H): 800*600*2100, Short Circuit 35kA, IP 20

Controller Ordering Information

Controller Type	Measurement Level	No. of Groups	Comm. Card		Power Supply	Special Type
EQC	3	12	2	-	2	WT

Controller Type	EQC	Equalizer Controller
Measurement Level	2	
	3	
No. of Groups		Number of Groups (Physical, two digits, max. 12)
Communication Card	0	No Communication
	1	RS 485 ELCOM Protocol
	2	RS 485 ELCOM and MODBUS/RTU Protocols
Power Supply	1	115V
	2	230V
Special Type		See Controller section on previous pages Up to two types can be combined

Measured Parameters

Parameter	Phases	Loads	Measurement Level 2	Measurement Level 3
Frequency	Common	Mains	£	£
Phase Current	L1, L2, L3	Mains,Load,Cap.	£	£
Neutral Current	Neutral	Mains	£	£
Phase to Phase Current*	L1-2, L2-3, L3-1	Mains , Load	£	£
Phase Voltage	L1, L2, L3	Mains	£	£
Neutral Voltage	Neutral	Mains	£	£
Phase to Phase Voltage	L1-2, L2-3, L3-1	Mains	£	£
Active Power (kW)	L1, L2, L3, Total	Mains	£	£
Reactive Power (kVAr)	L1, L2, L3, Total	Mains,Load,Cap.	£	£
Apparent Power (kVA)	L1, L2, L3, Total	Mains,Load,Cap.	£	£
Power Factor	L1, L2, L3, Total	Mains,Load,Cap.	£	£
Time of use (TOU) - in, out, net, total:				
Active Energy (kWh)	Total	Mains	£	£
Reactive Energy (kVARh)	Total	Mains	£	£
THD at Phase Current	L1, L2, L3	Mains,Load,Cap.	£	£
THD at Neutral Current	Neutral	Mains	£	£
THD at Phase to Phase Current	L1-2, L2-3, L3-1	Mains , Load	£	£
THD at Phase Voltage	L1, L2, L3	Mains	£	£
THD at Neutral Voltage	Neutral	Mains	£	£
THD at Phase to Phase Voltage	L1-2, L2-3, L3-1	Mains	£	£
Harmonics of Phase Current	L1, L2, L3	Mains,Load,Cap.		£
Harmonics of Neutral Current	Neutral	Mains		£
Harmonics of Phase to Phase Current	L1-2, L2-3, L3-1	Mains , Load		£
Harmonics of Phase Voltage	L1, L2, L3	Mains		£
Harmonics of Neutral Voltage	Neutral	Mains		£
Harmonics of Phase to Phase Voltage	L1-2, L2-3, L3-1	Mains		£
Waveforms of Phase Current	L1, L2, L3	Mains,Load,Cap.		£
Waveforms of Neutral Current	Neutral	Mains		£
Waveforms of Phase to Phase Current	L1-2, L2-3, L3-1	Mains		£
Waveforms of Phase Voltage	L1, L2, L3	Mains		£
Waveforms of Neutral Voltage	Neutral	Mains		£
Waveforms of Phase to Phase Voltage	L1-2, L2-3, L3-1	Mains		£
System Log			£	£
Event Log			£	£

* Unique feature: metering internal current of feeder transformer (delta secondary)

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