Life Expectancy and Efficiency in PFC systems

Life Expectancy and Efficiency means operation with high levels of Reliability, Safety and Durability.

Many factors contribute to have a good life expectancy and efficiency of a PFC system.

- **Network and Load Analysis**
- **Application Design**
- **Component Selection**
- **Panel Design**

Network and Load Analysis:

It all starts with a complete analysis of the network and the load, determining by measurements and picking up relevant data of the real working conditions regarding voltage and over-voltages, harmonics contents, short circuit power and configuration. A complete analysis of resonance risk, the requirements for capacitive reactive power needed to achieve a target power factor and the variability of the load.

Application Design:

Based on the network and load analysis the application design must define the most efficient solution and how is it going to be implemented. The target most of the times will be to reach a certain power factor but will have to deal with harmonics and eventually filter them, with the load variability, with the network and possible installation conditions. The target must be accomplished with the best available engineering techniques within the budget for the realization.
The application design must determine what kind of PFC technology is required , like standard , tuned or detuned filtering, in automatic or high speed dynamic ways.
The application design for the target and restrictions of the project will affect significantly the Life Expectancy and Efficiency of the solution implemented.

Component Selection:

Based on the application design, then the components selection must be done.
It must comprise all key components suitable for the application comprising not only the capacitors , but also switching devices, protections, reactors, controllers, etc.
Once again, the right selection of the components will affect Life Expectancy and Efficiency of the Solution implemented as much as the life expectancy and efficiency of the components themselves under their rated operation conditions.

Panel design:

Based on the application design and the components selection, the panel design must provide all the necessary means to the selected components for operating at the best conditions and must assure that never any maximum permissible value be exceeded.
Panel design should take care of heat dissipation, electrical protections, inrush current limiting, alarm conditions, even use of capacitors and efficient PFC performance.

Life Expectancy of PhaseCap Premium PFC Power Capacitors

Life Expectancy is based on a statistical analysis of capacitors performance under rated operational conditions, that means at rated voltage and rated current, while the specified limits for the temperature category be not exceeded.
PhaseCaps have a Life Expectancy of 115.000 hs (LEn) and have a –25/D category according to IEC 60831-1 (max average 35°C along a year, max 45°C along a day, absolute max 55°C)

Life Expectancy is derated mainly as a function of the following parameters:

- real operating voltage
- real I_{RMS} current
- real hot-spot temperature
- number of switching operations
- dumping of inrush currents

- Life expectancy is derated as function of the operating voltage.

The following approximation formula may be used **:**

LE = LEn . Xv

U=1,10 Un	→	Xv = 0,50
U=1,05 Un	→	Xv = 0,70
U=1,00 Un	→	Xv = 1,00
U=0,95 Un	→	Xv = 1,25
U=0,90 Un	→	Xv = 1,50

- Life expectancy is derated as function of the year average ambient temperature.

The following approximation formula may be used **:**

LE = LEn . X_T

T= 42 °C	→	X_T = 0,50
T< 35 °C	→	X_T = 1,00
T< 28 °C	→	X_T = 2,00

This derating in only approximate because it also strongly depends on the heat dissipation capability provided by the installation. What really counts, is the hot-spot temperature located at the hottest spot deep inside the winding, near the core and it's a must that the capacitor construction design and the mounting conditions take care of dissipating the internal heat in order not to exceed the maximum permissible hot-spot temperature value.

The maximum permissible hot-spot temperature is the highest temp at which the dielectric can withstand the rated voltage applied without any risk of over-stress, it depends on the technology of the dielectric used and on the manufacturer's thermal design and safety considerations.

The I_{RMS} current overload caused by harmonics and over-voltages increase internal power dissipation and consequently the internal hot-spot temperature.

Capacitors are designed for a maximum permissible I_{RMS} current up to 1,3 times I_N at rated sinusoidal voltage and rated frequency, excluding transients. Up to 1,5 times I_N considering harmonics, over-voltages and capacitance tolerance.

Resonance conditions provoke high I_{RMS} currents and over-voltages that may exceed all maximum permissible values. So, these conditions must be avoided by a proper application design.

The real hot-spot temperature depends on:

- the ambient temperature
- the power dissipation (considering dielectric and ohmic losses, both also influenced by the fundamental current and the harmonic contents)
- the thermal resistance (dependant on capacitor design and mounting conditions)

Some of these parameters are controlled by the capacitor manufacturer in the design process.
The design specifies the voltage stress and maximum hot-spot temperature at which capacitor will operate. Careful capacitor design sets low values for these parameters paying the price for thicker dielectric, bigger volume and sophisticated technologies but achieves far more reliable, safe, and long lasting capacitors.

Capacitor constructive design and technologies applied in PhaseCaps, like the concentric winding design, the quality and stress of the dielectric material used, the hot-spot maximum value used, the thermal design for heat dissipation, the WaveCut Film, the Gas impregnation and the quality of the manufacturing processes are the manufacturer controlled parameters that affect life expectancy. Although the user still plays a fundamental role in the right component selection.

But some other parameters strongly depend on the panel design, like the mounting conditions including position, ventilation, heat conduction, number of switching operations, proper discharge means, intelligent controllers, inrush current limiting, current overload and transient over-voltages.

PhaseCap capacitors are designed and manufactured with high technologies according to IEC 60831 standard which set maximun permissible values. It is important to always have in mind that these values define overload limits for different parameters that mainly affect the capacitor´s performance and life expectancy.

It´s not recommended to operate the capacitors at maximum permissible values.
The simultaneity of any of these overload conditions must be avoided and the installation guidelines should be follow to get the best results in performance and user´s satisfaction.

This life expectancy analysis is based on our Research & Development work, on long term endurance tests and on our field experience of having more than 2 millions MKK PhaseCap capacitors installed along 20 years.

For further in depth information please see EPCOS application notes “Thermal Design of Power Capacitors” and “ More Power with PhaseCaps” .