



KST POWER QUALITY
Technical note Cleanwave[®] KPS Rotary UPS

**IMPROVEMENT OF ELECTRICAL POWER SUPPLY
QUALITY WITH THE HELP OF
Cleanwave[®] KPS ROTARY UPS & CONDITIONER**



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1. FOREWORD

Rotary UPS systems will produce a very high quality uninterruptible power supply. The use of a rotating machine and robust component types enable the system to cope with electrical abuse (short circuits, harmonic currents & low p.f.) without having to resort to the utility supply or the addition of extra equipment to the input.

The **Cleanwave®** KPS is the optimum solution to network disturbances. IEC Standard 1000-2-2 identifies these disruptions as follows :

- Total power interruption
- Slow voltage fluctuations
- Overvoltage resulting from lightning or work on MV network
- Rejection of harmonic currents caused by non-linear loads
- Voltage drop-out and short interruption
- Unbalanced loads
- Rapid voltage variations (Flicker effect)
- Low power factor

2. INTRODUCTION

The vast majority of companies are moving nowadays towards the manufacturing of products with high added value. The more and more integrated control of industrial process is only possible with a high quality electrical power supply source. In the past, saving computer data and restarting the production cycle were a satisfactory strategy for most companies. Nowadays, the situation is very different. The increasing complexity of the manufacturing process requires to ensure a full reliability of all the equipments (motor speed controllers, instrumentation, microprocessors, furnaces, pumps, compressors, presses, CNC machines,...). The power of the loads requiring a high quality electrical power has significantly increased and reaches values of several hundreds kVA.

The **Cleanwave® KPS** fully meets the above described criteria and furthermore offers other advantages regarding the short-circuit current capacity, voltage regulation, $\cos \phi$ compensation, etc.

3. CONSTRUCTION

The **Cleanwave® KPS** is not only a UPS but also a mains conditioner for low and medium voltage and comprises of the following components :

- a brushless synchronous machine flanged coupled to a 1500rpm accumulator (ROTABLOC)
- a unique starting system
- a power cabinet with upstream, downstream & bypass motorised circuit breakers & switches
- a control cabinet with PLC, regulation cards and diagnostic displays
- a three-phase coil or inductance

For power ratings up to 300 kVA, all the above components are housed in a single soundproof cabinet as shown below.

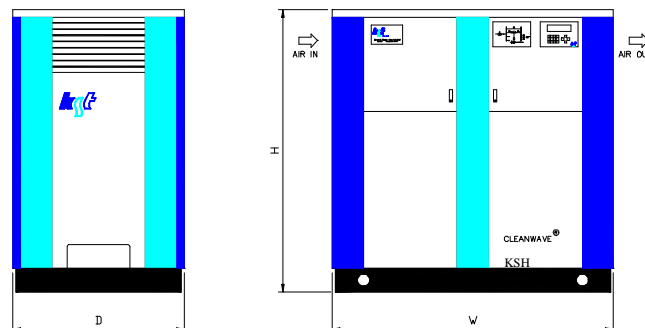


Fig.1

4. PERFORMANCE

The synchronous motor is connected in parallel to the L.V. via a damping coil. It runs, in normal conditions, as a traditional, well proven, synchronous compensator.

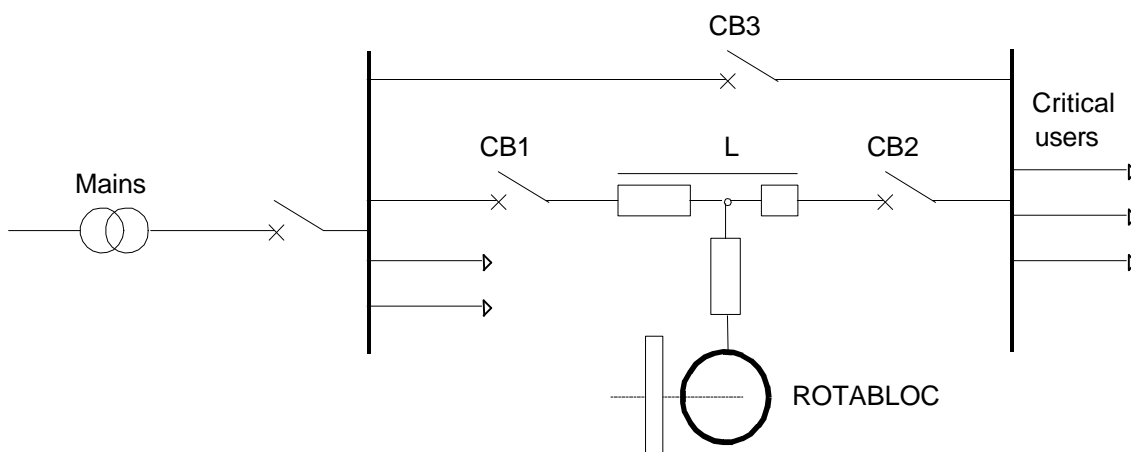


Fig.2

In this mode of operation, as shown in fig. 2, the **Cleanwave® KPS** system

- ❑ filters the **voltage harmonics** coming from the supply network.
- ❑ significantly reduces upstream pollution of **harmonic currents** generated by non-linear loads downstream
- ❑ maintains a **constant output voltage irrespective of either slow voltage fluctuations (+/- 15%) or rapid fluctuations (in particular the flicker effect around 16Hz)**.
- ❑ **Maintains a constant voltage** on the load during major transient **voltage dips** (regardless of the upstream Pcc) . This is possible due to the unique ER2 regulation card.
 - ❑ dU ≈ 30 % during 30 sec to 1min.
 - ❑ dU ≈ 40 % during 20 to 30 sec.
 - ❑ dU ≈ 50 % during 10 to 20 sec
 - ❑ dU ≈ 60 % during 6 to 10 sec
 - ❑ dU ≈ 100 % during 100 msec

Such voltage dips are generally caused by short-circuits or switching operations upstream. Supply networks that are prone to lightning strikes are also a contributory factor to voltage disturbance. The acceptable duration of voltage dips depends on the setting of the protection upstream of CB1.



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- ❑ due to its low subtransient reactance, **the setting for protection** devices downstream is simple and assured. A FLC of 17 to 20 x means that it is unnecessary to resort to the system bypass for fault clearing
- ❑ the **Cleanwave® KPS** automatically provides reactive power upstream. The power factor presented to the utility supply can be controlled by the alternator to provide a p.f. nearer to unity. This does away with the need for expensive capacitor banks.
- ❑ The ROTABLOC in conjunction with its choke eliminates voltage microcuts therefore major harmonic currents at high frequency are also attenuated due in part to the machines low impedance. The benefit to the user is improvement in the longevity of capacitor populated equipment, elimination of resonance with other elements of a network and prevention of nuisance tripping downstream. In addition peak currents caused by induction motor starting are reduced because the **Cleanwave® KPS** provides a reacting current during motor start up. The upstream supply only sees the active power peak.
- ❑ maintains low angular differences from one period to the other period during network disturbances and during significant load demand downstream.
- ❑ provides to the whole system a **very high efficiency** (greater than 96% for KPS-300). Indeed, the **Cleanwave® KPS** comprises a largely oversized synchronous machine with greatly reduced losses. The active power is directly supplied by the network to the load without passing through the synchronous machine which only supplies the reactive power.
- ❑ like any synchronous machine, the **Cleanwave® KPS** can be simply connected in parallel. This allows the user to provide for redundancy / resilience for future expansion of capacity.
- ❑ In normal conditions, the voltage regulators of synchronous machines ensure an equal sharing of the reactive powers between the N machines. In simple parallel systems, the maximum power that can be saved by the system is equal to $P \times N$. In redundant parallel systems, the maximum power that can be saved by the system is equal to $P \times (N-1)$. In the last case, we can obtain an almost total reliability of the **Cleanwave® KPS**.

5. ADVANTAGES OF THE Cleanwave® KPS SYSTEMS

The specifying Engineer should take note of the following points when selecting a high quality UPS system.

5.1. Efficiency.

As already mentioned, the operating and dimensional characteristics of the **Cleanwave® KPS** give to the whole system a very high efficiency (greater than 97,5% for a KSC 1000).

5.2. Performance in the face of load harmonic currents.

Some loads mainly comprise high power electronic equipment, which generate powerful harmonic currents. The low reactance of the synchronous machine fitted to the **Cleanwave® KPS** is particularly suited to the reduction of such harmonic currents on the user voltage wave shape.

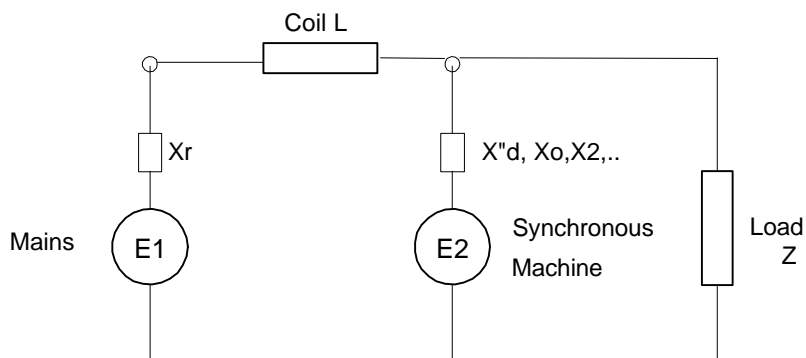


Fig.3

The whole network – damping coil – synchronous machine and load is represented in diagram fig.3.

In a first analysis, the reactances X_d'' , X_0 , X_2 are essential in order to assess the impact of harmonic currents on the shape of the voltage wave, and the part of these currents which are rejected towards the network upstream of the system. The above mentioned reactances demonstrate, on the one hand, the efficiency of the damping cage for quenching the variable fields which are in relative rotation with respect to the fundamental field and, on the other hand, the level of the stator leak flows.

The synchronous machines fitted to the **Cleanwave® KPS** are characterised by the following reactances :

- X_d'' and X_2 : < 5%
- X_0 : < 2%

If Z generates current such as :

$I_z = I_1 + I_3 + \dots + I_n$ with a harmonic rate of :

$$T = \frac{\sqrt{\sum I_v^2}}{I_1}$$

for any v different from 1, the previous diagram becomes fig.4

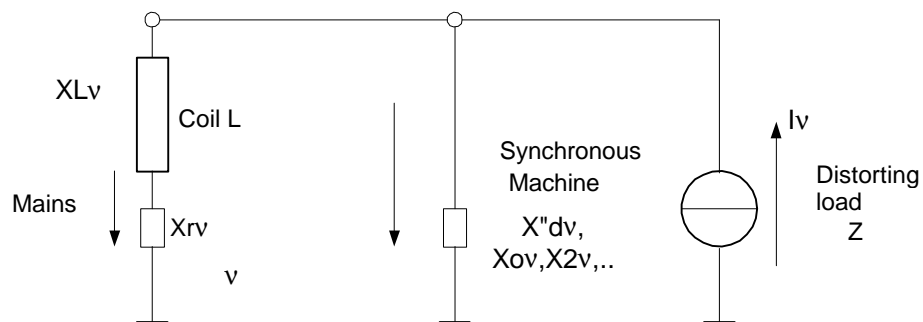


Fig.4

We know that

- the harmonics $I_7, I_{13} \dots I_{6k+1}$ provoke **directs** currents.
- the harmonics $I_5, I_{11} \dots I_{6k-1}$ provoke **opposite** currents.
- the harmonics $I_3, I_9 \dots I_{6k-3}$ provoke **homopolar** currents.

With :

- $X_{Lv} = X_L \cdot v$ for any harmonic, because of the conception of the coil
- $X_{Sv} = X_{\text{machine synchrone}, v} = X_0 \cdot v$ for the homopolar harmonics
- $X_{Sv} = X_d'' \cdot v \approx X_2 \cdot v$ for the direct and opposite harmonics.

The ratio between X_{Lv} and X_{Sv} varies according to the rank of n between 6 and 20. It results that :

- the current harmonic rate which is rejected upstream (network) is reduced by a factor of almost 10.
- the amplitude of the harmonic voltages at the terminals of X_S (proportional to the reactances X_0 and X_2) is low in comparison with the amplitude of conventional machines.

5.3. Influence of a distorted or unbalanced network voltage.

An unbalanced three-phase voltage can be replaced by three balanced three-phase systems E_d , E_i et E_0 . The diagram of fig.3 becomes changes as fig.5.

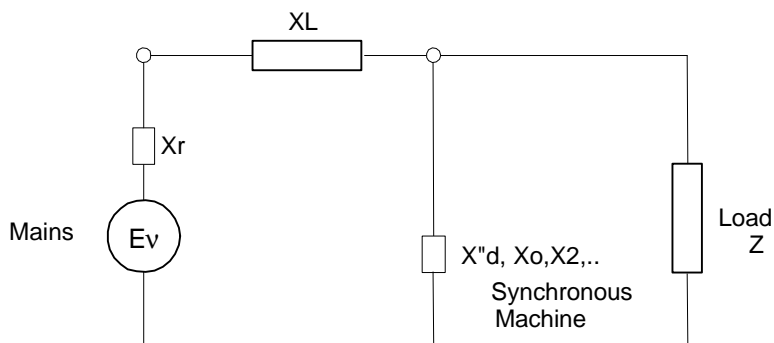


Fig.5

In this case, the reactances X_{0v}, X_{2v}, \dots play, in comparison with the inductance X_{Lv} , the role of a voltage divider. By replacing the reactance values by the corresponding values according the harmonic order or the values resulting from the transformation in symmetrical components, we can observe the drastic reduction in the amplitude of the distortions.

The equations governing the system are valid for any sinusoidal voltage different from the fundamental voltage wave.

Consequently, they apply to :

- ❑ quick voltage fluctuations (**Flicker** effect), which can be considered as the superposing of a fundamental voltage wave with a voltage, the frequency of which is a submultiple of the fundamental frequency.
- ❑ in the same way, the voltage or current **inter-harmonics** will be reduced in the same proportions as those of other harmonics.

Such particular cases, frequently met in the industry and reduced with a lot of complex technological difficulties, are, with the **Cleanwave® KPS** system, naturally reduced. These last two cases of disturbance of the voltage wave are illustrated in fig.6

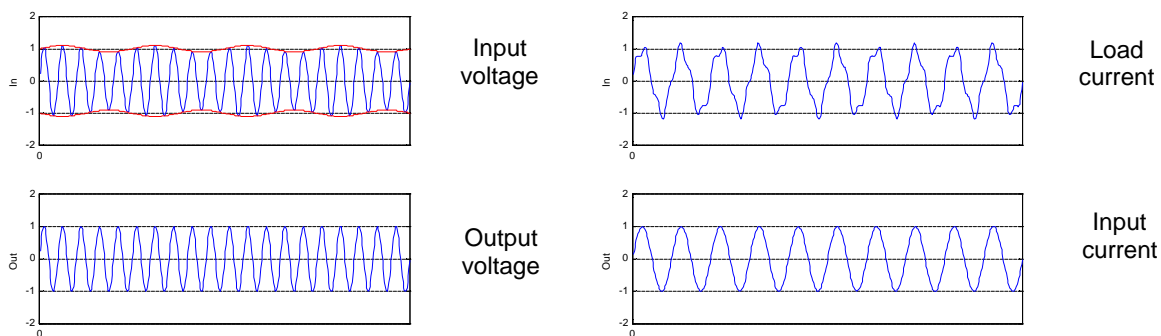


Fig.6

5.4. Dynamic performance.

The system responds outstandingly well to all disturbances coming from the network :

- ❑ Slow and transient voltage dips;
- ❑ Loads imposed by users;
- ❑ Short-circuits upstream of the MV network, frequent during thunderstorms;
- ❑ Slight angular differences during network disturbances and imposed loads, as well as during major load demands by users.

We will now explain the first point, which concerns the preservation of the voltage at the user terminals in case of major network voltage dip. With this aim in view, we will adopt the following conventions (fig.7).

In order to avoid heavy vectorial constructions, the diagram is intentionally simplified.

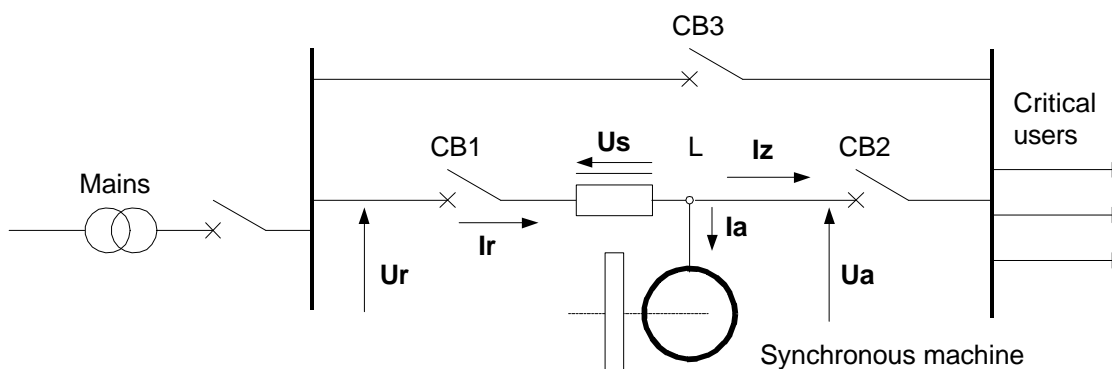


Fig.7

When operating in synchronised mode on a network, the **Cleanwave® KPS** system acts as a synchronous compensator. In this situation, the current supplied by the synchronous machine is in quadrature with the U_a voltage. The machine does not absorb any active power except its low no-load losses. Furthermore, the network current is in quadrature with the coil voltage U_s . This voltage U_s represents the vectorial difference between the network voltage and the user voltage.

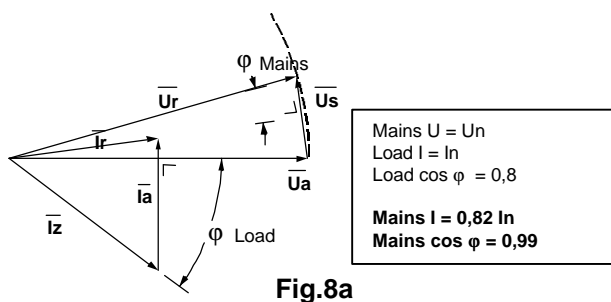


Fig.8a

Fig.8a represents the vectorial diagram of the voltages and currents which pass through in the system when the network voltage is close to the user voltage (within $\pm 1\%$), and the load is nominal with $\cos \varphi = 0,8$. We immediately observe that the current which passes upstream of the system is almost 20% lower than the current absorbed by the load. The system fulfills its role as a synchronous compensator by supplying almost all the reactive currents absorbed by the load, so that the network $\cos \varphi$ is close to 1.

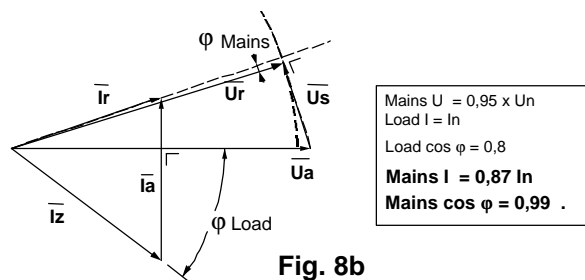


Fig. 8b

Fig. 8b & 8c represent the same diagrams when network voltages are respectively 5% lower and 5% higher than the nominal voltage.

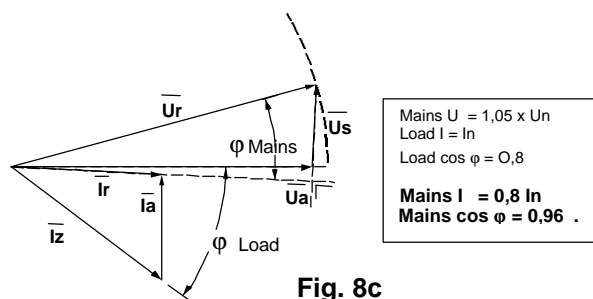
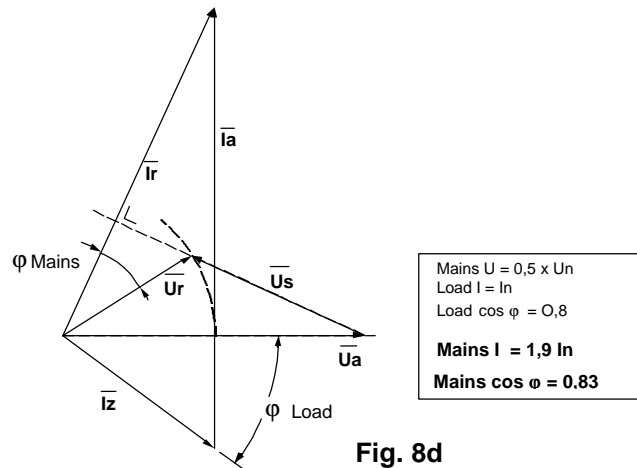


Fig. 8c

Fig.8d illustrates the case of a major voltage dip during which the network voltage has fallen by 50%. We note that the voltage at the user terminals can be maintained at its nominal value provided the synchronous machine is able to supply a large reactive current.



It has been observed that the synchronous machines of the **Cleanwave® KPS** systems are largely oversized; thus the supply of large reactive currents is not a problem. Only the setting of the circuit breaker upstream (overcurrent at the level of I_r) will limit this kind of operation in the time. The diagrams above are represented in steady state, the transition from one state to another is not a problem but cannot be explained within the scope of this short presentation.

5.5. High MTBF and low MTTR.

The system is compact and robust, at the level of the control system as well as at the level of the rotating machine. The power controlled by the control and regulation boards do not exceed a few tens of watts, which enables an important oversizing of all the electronic components and ensures a very high reliability. Simple maintenance with a possible redundant uni increases these qualities.

5.6. High short-circuit power.

The low value of the reactances gives the system a Pcc close to the Pcc of the existing supply network. So, it is not necessary to allow for the cost of modification of the users selective protection.



6. CONCLUSIONS.

The advantages described in this technical document prove that the **Cleanwave®** KPS solves almost all the network quality problems which can arise.

Besides these advantages, it is important to know that, in the industrialized countries, almost all disturbances result from micro-cuts. These micro-cuts can be categorised in terms of magnitude and duration and are shown below as a typical statistical representation. This correlates to IEC UNIPED table :

Duration(t) Depth %	10ms to <100ms	100ms to <500ms	500ms to <1s	1s to <3s	3s to <20s	20s to <60s
10 to < 30	111	68	12	6	1	0
30 to < 60	13	38	5	1	0	0
60 to < 100	12	20	4	2	1	0
100	1	12	16	3	3	4

(■ disturbances "eliminated" by the **Cleanwave®** KPS)

When we examine this table, we observe that more than 80% of the disturbances are "eliminated" by the **Cleanwave®** KPS.

Therefore, the conditioning abilities of the KPS will increase the reliability of a network by a factor of 5 and should the ridethrough UPS abilities of the KPS be used in conjunction with an upstream genset then the total reliability increases tremendously.