

## APC Silcon UPS and Diesel Generator

### Abstract

The APC Silcon UPS has the highest efficiency (AC-AC on-line UPS), at the same time as the input power factor has been regulated to 1, and input current is sinusoidal. This means that APC Silcon has the lowest input power compared to any other UPS systems sold in the market today. In this way it is easy to have APC Silcon operating correctly on a diesel, simultaneously with the very flexible software programming of APC Silcon. At development of the APC Silcon series great efforts have been made as regards control, regulations, as well as optimizing the whole operational mode of the APC Silcon UPS making it completely optimal for operation on a diesel generator.

### Introduction

UPS and diesel generator are two factors, which are closely united when it comes to ensuring the supply reliability at critical installations. Especially in connection with longer back up times, typically >20min., it may be worth using a small battery together with a diesel generator to meet the requirements for back up. However, very often the installation consists of a critical part e.g. a computer and a less critical installation e.g. lighting, air condition. In connection with such an installation the most advantageous constellation is to have the diesel generator supplying the less critical load, while the UPS is supplying the most critical load. In that case the diesel generator will supply energy to the UPS after start-up, meaning that the batteries are being saved.

However, experience from many installations has shown that it is not always that easy to have UPS and diesel working together, as they are both regulated systems, enabling them to interact their regulators, which may result in instability. As the UPS is typically the greatest single user on the diesel generator, it is an advantage to optimize in the UPS to stabilize the total system, even if the UPS is not the factor causing the instability. To ensure an optimized interaction between diesel generator and APC Silcon UPS more parameters can be re-programmed by the keypad on the front, which makes the APC Silcon UPS very flexible.

### Definitions

**Slew rate** (Hz/Sec.) means, how fast a frequency change takes place. For example: From 52Hz to 50Hz in 4 seconds results in a slew rate of (2/4) 0,5Hz/Sec. The load determines the choice of slew rate. If it is a SMPS load (Switch Mode Power Supply) 4,0Hz/Sec. can be used, but if it is rotating loads or phase controls 1,0Hz/ Sec. can typically be used. In case of



## Example of real life test APC Silcon 480kW 400V

### Generator Type

Type : ANSALDO

### Diesel engine

Type : DORMAN Turbo diesel

Type effect : 600Hp

Cylinder capacity : 24L

Nos. of cylinders : 6

### Generator system

Type : Mobile generator system

Model : SGC 625

Serial : 670/791

kVA/kW : 625/500

Volt : 380

Phases : 3

Hz : 50

RPM : 1500

AMPS : 950

Furthermore, the generator is equipped with manual control of the reference for output voltage. This means that the generator can be adjusted in the area 335V RMS -480V RMS. The control of the generator system is electronic. During test the generator is adjusted to 400V RMS output voltage.

### APC Silcon UPS Series type

Standard : APC Silcon 480kW

DC supplied from a 12 pulse charger 800V DC, 800A

Output voltage : 400V

### Measuring on 480kW supplied from diesel generator

The following test has been carried out on the 480kW, when supplied from diesel generator. From battery to normal operation with 100% resistive load and supplied from diesel generator.

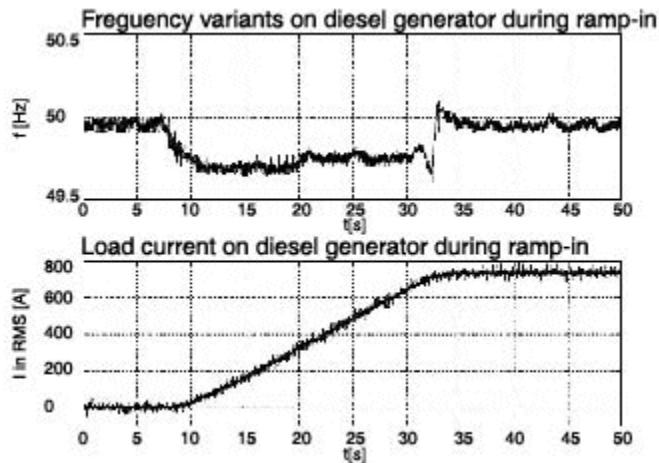
Slew rate = 2Hz/Sec. and ramp-in time = 10 seconds

Slew rate = 2Hz/Sec. and ramp-in time = 40 seconds

Output voltage and generator voltage at 100% resistive load

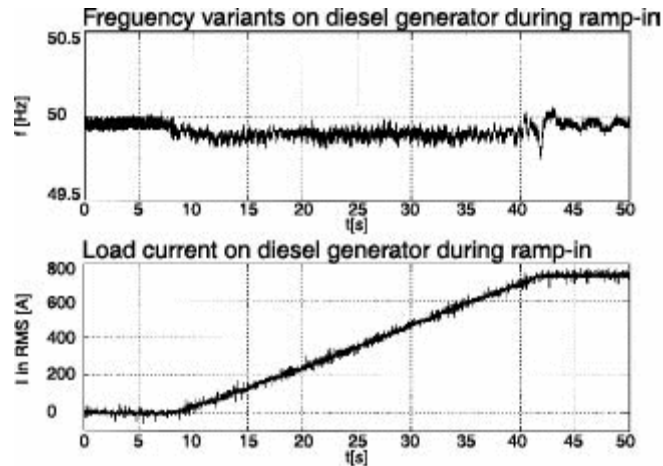
## Test results

Fig. 1 shows the frequency variation and the load current on the diesel generator during a ramp-in on the generator with 100% resistive load. The ramp-in starts at approximately 3 seconds, and it is shown that the generator frequency decreases with approximately 0.125Hz/Sec. to 49.75Hz. This frequency is kept until the ramp-in stops at  $t = 13$  seconds. Then the generator increases to 50Hz again.



*Fig. 1: Ramp-in on diesel generator where 480kW is loaded with 100% resistive load. 480kW is adjusted with: Slew rate = 2Hz/Sec. and ramp-in = 10 seconds*

Fig. 2 shows the frequency variation and the load current on the diesel generator during a ramp-in on the generator with 100% resistive load. The ramp-in starts at approximately 7.5 seconds, and here it is shown that the generator frequency decreases with approximately 0.02Hz/Sec. to 49.85Hz. This frequency is kept until the ramp-in stops at  $t = 42.5$  seconds. Here the generator increases to 50Hz again.



*Fig. 2: Ramp-in on diesel generator where 480kW is loaded with 100% resistive load. 480kW is adjusted with: Slew rate = 2Hz/Sec. and ramp-in = 40 seconds*

Fig. 3 shows the output voltage on the diesel generator and 480kW respectively. 480kW is running in normal operation with 100% resistive load.

Due to the sinusoidal input current of the APC Silcon UPS the distortion (THD) of the output voltage of the APC Silcon is very low.

If it had been a double conversion UPS with for example 6-12 pulse charger, the distortion would have been considerably higher. This might cause that UPS would not accept the voltage and with that the diesel generator.

This is a very important point at large-sized installations the UPS not being the only load on the diesel generator. In these cases a UPS with 6 or 12 pulse charger may cause such a high distortion that the equipment connected directly to the diesel generator may not accept it, even if accepted by the UPS. Therefore it is a general rule that the generator must be approximately 3-5 times larger than a double conversion UPS to obtain an acceptable distortion of approx. 8-10%. Not an unessential factor when buying the diesel generator.

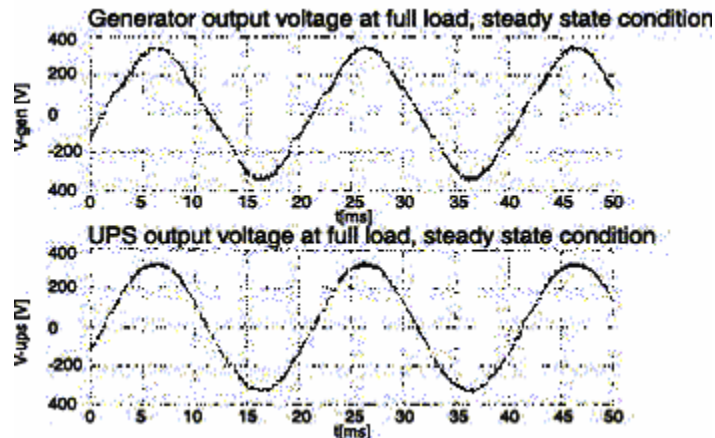


Fig. 3: Top: Output voltage on the diesel generator.

Bottom: Output voltage on 480kW. Here 480kW is loaded with 100% resistive load.

A number of measuring on the 480kW supplied from diesel generator has been carried out. Fig. 1 and 3 show that the ramp-in time on the generator has an influence on how much the frequency on the generator decreases at ramp-in and on how much the frequency changes when the ramp-in ends. Therefore some additional tests have been carried out on the 480kW, showing that if a long ramp-in time is chosen, then the slew rate can be de-decreased. This is important if a short ramp-in time is wanted, because then a higher slew rate time has to be accepted. By installation of systems with diesel generator, both slew rates as well as ramp-in time have therefore to be adjusted to the used generator. The total conclusion is that 480kW has handled the diesel operation to satisfaction.

## Requirements of the diesel generator

When dimensioning the diesel generator for an APC Silcon UPS is aware of the following recommended requirements:

### kVA rating

As APC Silcon has PF 1 on the input, there is no requirement of kVA rating of the generator.

### kW rating

When APC Silcon is going to operate on the diesel generator, the batteries of the APC Silcon UPS have already been discharged. Therefore the generator must take over full charging power, loss in inverter, as well as load.

On figure 4 the input current of the APC Silcon can be calculated using table and curve.

kW rating can then be calculated as follows

$$P_{\text{GENERATOR}} = \sqrt{3} \times V_{\text{GENERATOR}} \times I_{\text{IN APC Silicon}}$$

At 100% load it is typically 1,2 times the power rating of APC Silicon.

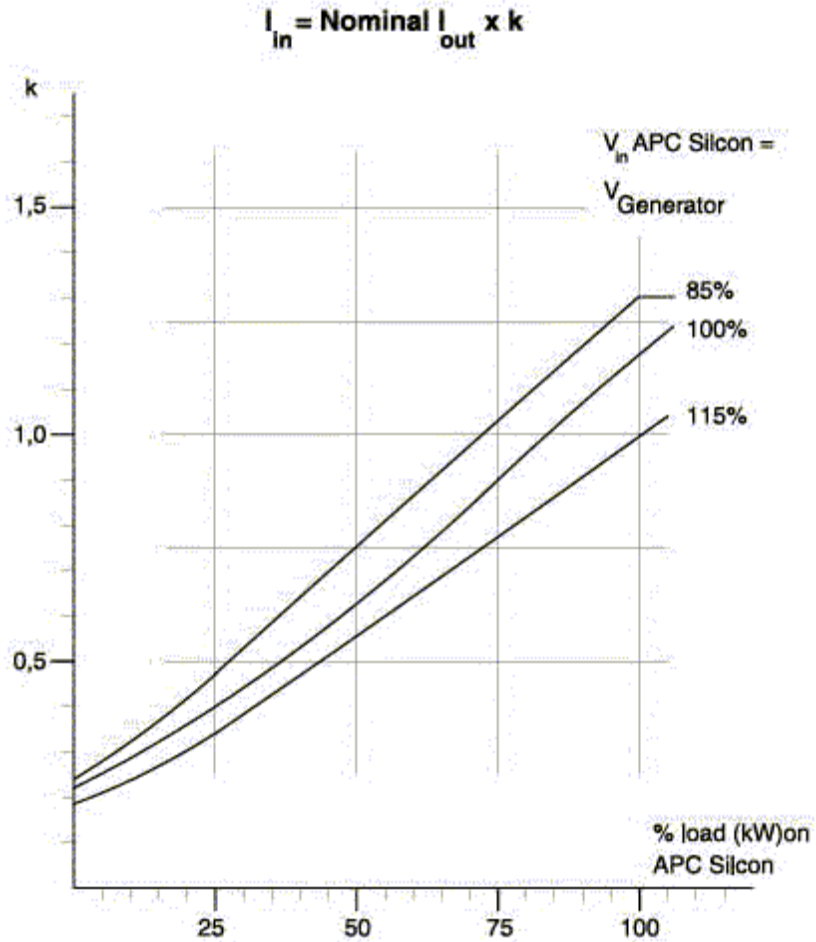


Fig. 4: Input current of the APC Silicon Series

*Nominal Out [A]*

APC Silcon	10kW	20kW	40kW	60kW	80kW	120kW	160kW	240kW	320kW	480kW
<b>380V</b>	15.2	30.3	60.6	90.9	121	182	243	365	486	729
<b>400V</b>	14.5	29.0	58.0	87.0	116	173	231	346	462	693
<b>415V</b>	13.9	27.8	55.6	83.3	111	167	223	334	446	669

**Voltage tolerance**

The voltage has to be inside  $\pm 15\%$ . However, if other equipment is connected, the requirement will typically be max.  $\pm 10\%$  or less.

**Frequency tolerance**

The generator must unloaded as well as fully loaded be able to keep the frequency inside the tolerances specified by the customer; this is valid for both dynamic and static. Max.  $\pm 8\%$ , typical  $\pm 6\%$ .

**Dynamic requirements (Load step)**

When APC Silcon is connected to the generator, the programmed soft start (ramp-in) will be used. Thus the diesel generator must be able to stand up to this load step from 0 to 100% within the specified time and simultaneously keep the frequency tolerance as well as the voltage tolerance during the whole course. Expect that the diesel generator is 'cold' when starting up. Max. time 40 seconds

**Distortion (THD)**

No requirements from APC Silcon UPS, however if other equipment is connected to the generator, THD should be max. 10%.

All above-mentioned requirements take into account that APC Silcon is supplying the load, and in this way operates as a filter between load and generator. However, take into account that APC Silcon may be in electronic bypass or maintenance bypass, causing that the diesel generator must directly stand up to the load.

When building up an installation consisting of UPS and diesel generator it is important to allow for an intelligent interaction between diesel generator and UPS. APC Silcon has a built-in advanced mains control, which controls the following parameters:

Frequency tolerance : Min. and max. value.

Frequency changes (slew rate) : Max. value.

Mains voltage RMS : Min. and max. value.

Mains voltage : Momentary value min. and max.

If these values are exceeded, APC Silcon will switch to battery operation and after a delay of 30 seconds a relay on System Integration Interface (SII X005 pin 13-14 battery operation) will be activated. This signal can be used for starting signal to a diesel generator. A simple mains control (typically only under voltage) may be built into the control of the diesel generator, starting up the generator in case of mains failure, but signal from the APC Silcon **must** be able to start the diesel generator too, otherwise the UPS may switch to battery operation on account of mains failure without the diesel generator starting up, as it may not 'see' the mains failure. When the diesel generator is operating, mains is turned off and diesel is turned on by means of two contactors. When the diesel generator is operating, everything is in a steady-state situation; therefore switch back should not take place until ensured that the main is healthy again.

Once the diesel generator is operating, it should operate for a certain minimum of time, e.g. 10-30 minutes, due to the lifetime of the engine. In this period of time the battery of the APC Silcon UPS is being charged too, so that there is enough energy left to switch over from diesel to mains.

When switching back to mains supply the diesel generator can with advantage be synchronized to mains, then switch over to mains can be uninterrupted. If the diesel generator is not synchronous, there must be a delay of approx. 100mS between the switchovers to ensure other equipment against phase changes (equipment not being connected to the APC Silcon UPS).

## NOTE

If the battery is small, and the diesel generator is slow starting simultaneously with a max. ramp in time, the diesel generator should operate for a longer time to ensure that the APC Silcon UPS is able to charge the battery sufficiently.

