TODAY'S AGENDA

LED-based Airfield Lighting

1. Discussion of the problems observed.
2. How to remediate them in the field.
3. How to avoid them in future.

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LED-BASED SOLID STATE LIGHTING (SSL)

SSL - A Burgeoning Concern on the Airfield

1. Series Circuits are no longer Resistive in nature
   - *Reduced **PF** will mean higher energy costs*
2. AFL suppliers do not design to any standard Input Impedance
   - *Operational results will vary by Manufacturer*
3. Regulators are becoming overloaded
   - *Airside Operations impaired by equipment failure*

1. Impact on New Construction Projects
   - *Under sizing of CCRs, Failures during Start-up, Additional labor costs*

Lost Time and Money!

CCR Technologies

SCR vs. Ferroresonant CCRs

Type	Output Waveform Shape	[1] Power Factor	[2] Output Current Regulation	[3] Flashing Loads	Total Harmonic Distortion	Price
SCR	Good	> 95%	Good	Good	Poor	Lower
Ferro-Resonant	Better	> 95%	Better	Better	Better	Higher

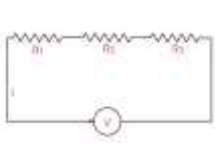
1. PF as measured at Full Load at Brightness 5.
2. Output Regulation into a Reactive Load (Spec = max. 30% lamps out)
3. Ability to regulate the output under flashing loads (Strobes, RGLs, etc.)

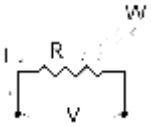
RESISTANCE - REACTANCE - IMPEDANCE

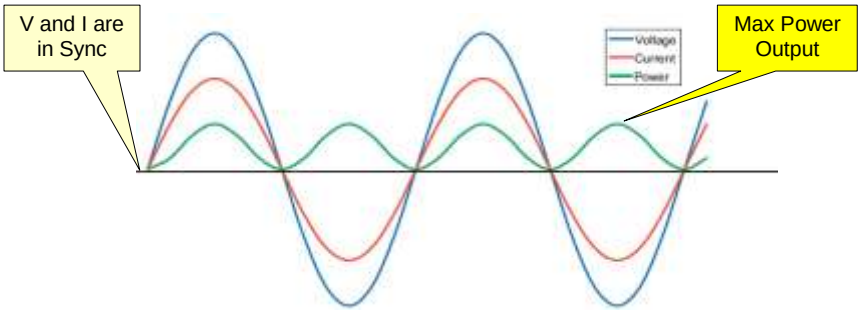
Incandescent Lighting

Essentially a 100% resistive load (the good old days!)

- *Near unity Power Factor*



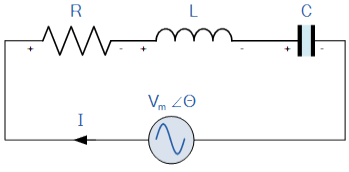




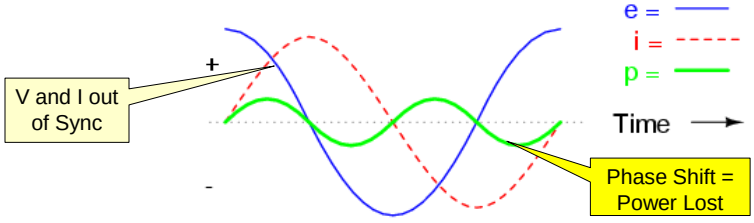
RESISTANCE - REACTANCE - IMPEDANCE

LED Lighting

No longer purely resistive – power supplies include Inductors and Capacitors to make them Reactive



- When $X_L > X_C$ the circuit is Inductive
- When $X_L > X_C$ the circuit is Capacitive
- Total circuit reactance = $X_T = X_L + X_C$ or $X_C - X_L$
- Total circuit impedance = $Z = \sqrt{R^2 + X_T^2} = R + jX$



Power Losses in the Series Circuit

What does this mean to the CCR and Energy Costs?

Inductance and Capacitance will distort the CCR output waveform

- *The LED load profile presented to the CCR is dynamic.*
- *Each LED circuit will have a different PF for <u>each</u> brightness step.*

<u>Series Circuit PF Calculation</u>

$$P.F. = \frac{KW}{KW - KVAR}$$

$$P.F. = \frac{Beer}{Beer + Foam}$$

$$P.F. = \frac{KW}{KVA}$$

A CCR supplies constant current, not constant kVA

CCR Loading

LED Loads - Effect on CCRs

With LEDs, the series circuit is no longer purely resistive

- Capacitance & Inductive <u>Reactance</u> is introduced to the series circuit
- Circuit becomes Reactive instead of Resistive (PF < 1)

Example:

G.A. Airport – LED Signs & Edgelights with 15kW Ferro CCR

	4.8A	5.5A	6.6A
kW	3.5	5.5	5.9
kVA	9.2	11.1	14.1
Vout	1,908	2,013	2,141
PF	0.38	0.50	0.42
CCR Loading	61%	74%	94%

A CCR supplies constant current, not constant kVA

CCR LOADING

LED Loads – Improving the PF

Find a lighting manufacturer that designs LED devices to appear as resistive to the series circuit.

- *Use LED NAVaids that have a stable PF between B1 - B5*
- *Look at the PF for all brightness steps*

Example: LED Signs with 20kW CCR (i.e., no other loads connected)

A	W	PF	VA	V	Brightness
2.8	35.3	**0.9986**	35.3	12.6	1
3.4	35.8	**0.9985**	35.9	10.5	2
4.1	36.6	**0.9983**	36.7	8.9	3
5.2	37.9	**0.9977**	38	7.3	4
6.6	40.1	**0.9967**	40.2	6.1	5

CCR LOADING

LED Loads – Operating Conditions Observed or Reported

- Initial Turn on of Circuit - CCR trips off on “OPEN CIRCUIT”
- Rapid rise of Voltage
- Current doesn’t get to step

- Running sign loads at lowest step – may cause CCR overloading
- Increased KVA loading
- CCR growling or loud

CCR – CAPABILITIES - FERRORESONANT CCR

Maximum Load Capacity of Ferroresonant type CCRs

NOTE: Limited by Max Impedance @ Max Step B5/B100

Nominal Rating (KW)	Nominal Output (Amps)	Output Impedance Z Max	Step Setting	Step Output Current (Amps)	Max KW @ step
10	**6.6**	230	B5 or B100	6.6	10.00
			B30	5.5	6.94
			B4	5.2	6.21
			B10	4.8	5.29
			B3	4.1	3.86
			B2	3.4	2.65
			B1	2.8	1.80

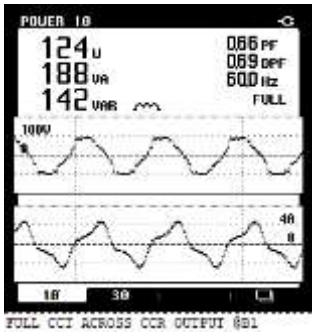
CCR – CAPABILITIES - THYRISTOR TYPE CCR

Maximum Load Capacity of Thyristor type CCRs

NOTE: Limited by Max Nominal Output Voltage of Transformer

Nominal Rating (KW)	Nominal Output (Amps)	Nominal Output Voltage	Step Setting	Step Output Current (Amps)	Max KW @ step
10	**6.6**	1515	B5 or B100	6.6	10.00
			B30	5.5	8.33
			B4	5.2	7.88
			B10	4.8	7.27
			B3	4.1	6.21
			B2	3.4	5.15
			B1	2.8	4.24

1 KW CCR – LOAD - MIX 4 SIGNS AND 10 TAXI EDGE

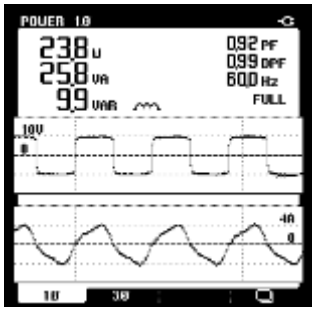


FULL CCT ACROSS CCR OUTPUT @B1

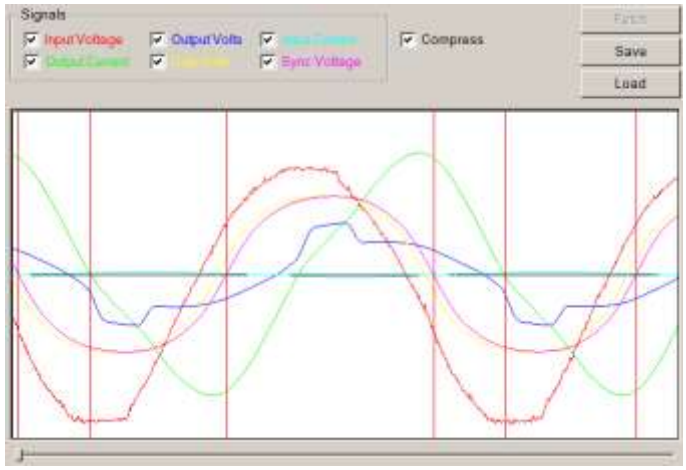
FULL CCT ACROSS CCR OUTPUT @B5

1 KW CCR – INDIVIDUAL EDGE LIGHT LOAD

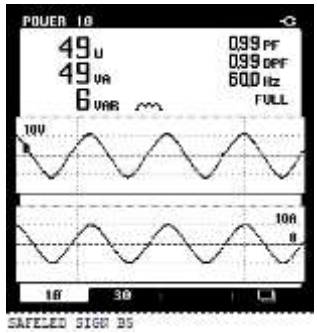
1 KW CCR – LOAD OF INDIVIDUAL SIGN LOAD



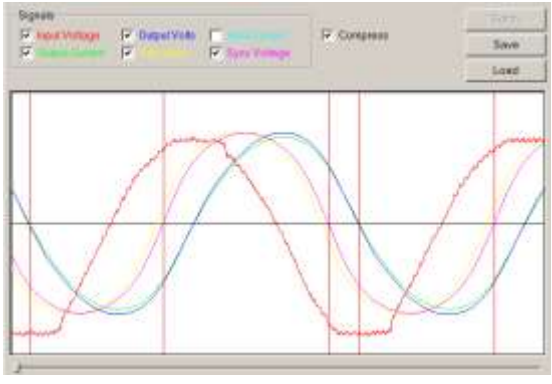
1 KW CCR – WAVEFORMS FOR SAME LOAD



LED SIGN LOAD – WITH RESISTIVE LOAD PROFILE



CCR – WITH FULL RESISTANCE LOAD



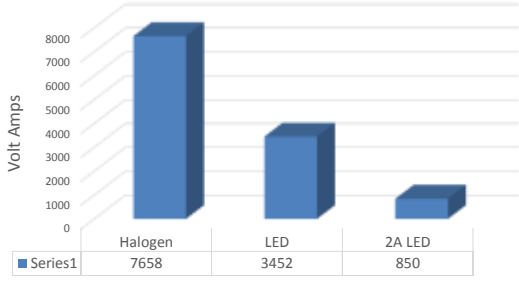
An Alternative to the 6.6A LED

Saving Power – the 2A. Solution

- AFL NAVaids manufactured to operate on both 6.6A or 2A circuits
- AFL designed to appear as resistive loads to the CCR
- Power savings are reduced by 90%

Example: 100 TWY Lights on 20,000' series circuit with 125' secondary cables

Halogen vs. 6.6A LED vs. 2A LED



In Closing

To minimize the impact of SSL on the airfield …

1. Select products with a consistent Power Factor across all brightnesses.
2. Size CCR circuits in accordance with published SCR and Ferro maximum power ratings for each output brightness level.
3. Ask what can be done to modernize FAA AC test specifications and to standardize impedance matching of AFL equipment.

Questions?