CIVIL AVIATION AUTHORITY OF FIJI

GUIDANCE MATERIAL

Aerodrome Electrical Systems – Constant Current Regulators

GM – AES (CCR)

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PREFACE

This Guidance Material (GM) has been developed by the Civil Aviation Authority of Fiji (CAAF) to assist CAAF inspectors, aerodrome operators, and contractors when selecting, installing, commissioning, and maintaining Constant Current Regulators (CCRs) used in aeronautical ground lighting (AGL) series circuits. It provides practical guidance to support consistent assessment and safe outcomes.

This GM is not a substitute for the applicable legislation, regulations, and standards. Where a conflict exists, the legal instrument or referenced standard prevails.

CAAF will review and update this GM as required to reflect lessons learned, technology changes, and international best practice. Comments and suggestions are welcome.

Chief Executive
Civil Aviation Authority of Fiji

RECORD OF AMENDMENTS AND CORRIGENDA

AMENDMENTS

No.	Date applicable	Date entered	Entered by
1	06/01/26	06/01/26	SOSC-GS
2			
3			

CORRIGENDA

No.	Date of issue	Date entered	Entered by

2.1.2 Table of Contents

Abbreviations

Abbreviation	Meaning
AC	Alternating current
AGL	Aeronautical ground lighting
AGL (height)	Above ground level
CCR	Constant current regulator
DMM	Digital multimeter
DSP	Digital signal processor
EMC	Electromagnetic compatibility
EMI	Electromagnetic interference
EPR	Ethylene propylene rubber
MDT	Mean downtime
MR	Multifaceted reflector
MTBF	Mean time between failures
PAPI	Precision approach path indicator
PUR	Polyurethane
PVC	Polyvinyl chloride
RMS	Root mean square
VA	Volt-ampere
VOM	Volt-ohm-milliammeter / volt-ohm-meter
XLPE	Cross-linked polyethylene

1. INTRODUCTION

Constant Current Regulators (CCRs) provide controlled current to aeronautical ground lighting (AGL) series circuits. They are a critical safety component because they influence light intensity, circuit protection, and fault indication.

1.1 Purpose

This GM explains key CCR concepts and sets out practical guidance for selection, installation, commissioning, and ongoing maintenance. It also provides inspection prompts to support consistent assessment.

1.2 Scope

This GM applies to CCRs used on aerodrome AGL series circuits (e.g., runway, taxiway, and approach lighting), including CCR replacement, upgrade, or new installation.

1.3 References

The following references are commonly used when developing or assessing CCR installations:

- ICAO Annex 14 — Aerodromes (Volume I) (as applicable).
- ICAO Aerodrome Design Manual (Doc 9157), Part 5 — Electrical Systems (as applicable).
- IEC 61822 — Electrical installations for lighting and beaconing of aerodromes — Series circuits for AGL.
- Manufacturer's installation, operating, and maintenance manuals for the specific CCR model.

1.4 Safety Notice

AGL series circuits can develop hazardous voltages, particularly under open-circuit conditions. Only trained and authorised personnel should install, test, or maintain CCRs, using appropriate isolation and lock-out/tag-out procedures.

2. OVERVIEW OF CONSTANT CURRENT REGULATORS

A CCR is designed to maintain a nearly constant output current despite changes in load or input voltage. This supports consistent light output over long series circuits and enables controlled intensity steps.

2.1 Types of Constant Current Regulators

2.1.1 The CCR types most commonly encountered in AGL applications include:

- Moving coil regulators
- Resonant network (monocyclic square) regulators
- Saturable reactor regulators
- Solid-state (SCR) regulators
- Ferroresonant regulators
- Pulse-width modulation (PWM) regulators (typically for LED AGL systems)

2.1.2 Most aerodrome ground lighting series circuits are powered by constant current regulators (CCRs) to maintain consistent light intensity over long distances (e.g., runways). CCRs provide a constant output current despite variations in circuit load and input supply voltage, and typically offer two or more selectable current steps to enable light dimming. Common CCR types used for aerodrome lighting are described below.

2.2 Moving Coil Regulators

2.2.1 Moving coil regulators use mechanically separated primary and secondary coils. Movement changes the magnetic coupling to regulate output current.

2.2.2 Key points:

- Historically common for series circuits.
- Requires stable installation (level and vibration-isolated).
- Mechanical components can increase maintenance requirements.

2.2.3 Moving-coil regulators have long been used to supply constant current to series lighting circuits (including street lighting). They use separate primary and secondary coils that move relative to each other, varying the magnetic leakage reactance so the regulator automatically maintains a constant current despite changes in load or input voltage. The moving coil "floats" to a position of mechanical equilibrium, with the repulsion force balancing its weight; output current is adjusted using a counterweight (Figure 2-1). Light intensity is controlled using a tapped transformer on the regulator output.

2.2.4 Key disadvantages are the mechanical movement (requiring precise levelling and vibration isolation) and poor power factor at partial loads (e.g., around 75% or less at 50% load).

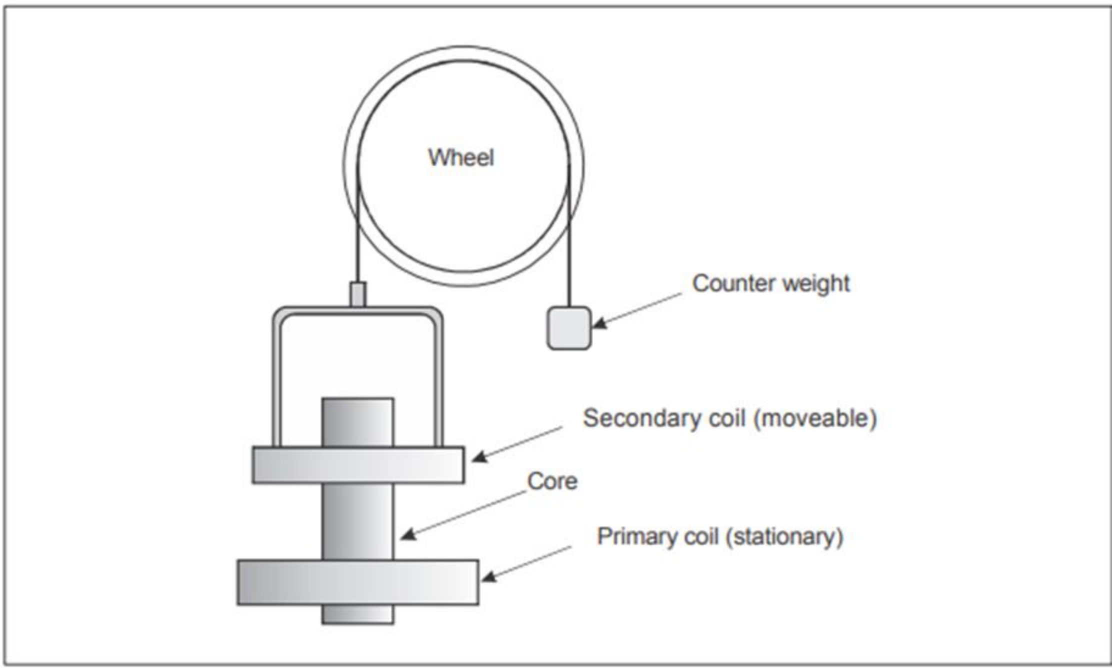

Figure 2-1. Moving coil regulator

2.3 Resonant network (monocyclic square) regulators

2.3.1 A static regulator where an inductive-capacitive network regulates current, typically via a bridge-type circuit.

2.3.2 Key points:

- No moving parts and generally high-power factor.
- Less tolerant of input voltage variation unless additional compensation is provided.

2.3.3 The current regulating network usually consists of two inductive coils and two capacitors, each of equal reactance (resonance) at the power frequency, arranged in a bridge-type circuit. With such a network, the secondary current is independent of the impedance of the load. Intensity control can be provided by a tapped input or output transformer or by a continuously variable input transformer. The advantages of this type of regulator are no moving parts and a high-power factor. The disadvantages are a lack of compensation for variations in input voltage and adverse effects on the regulation caused by loads that cause high harmonic frequencies in the resonant circuit, such as open-circuited secondaries of series isolating transformers and gaseous-vapour lamps (see Figure 2-2).

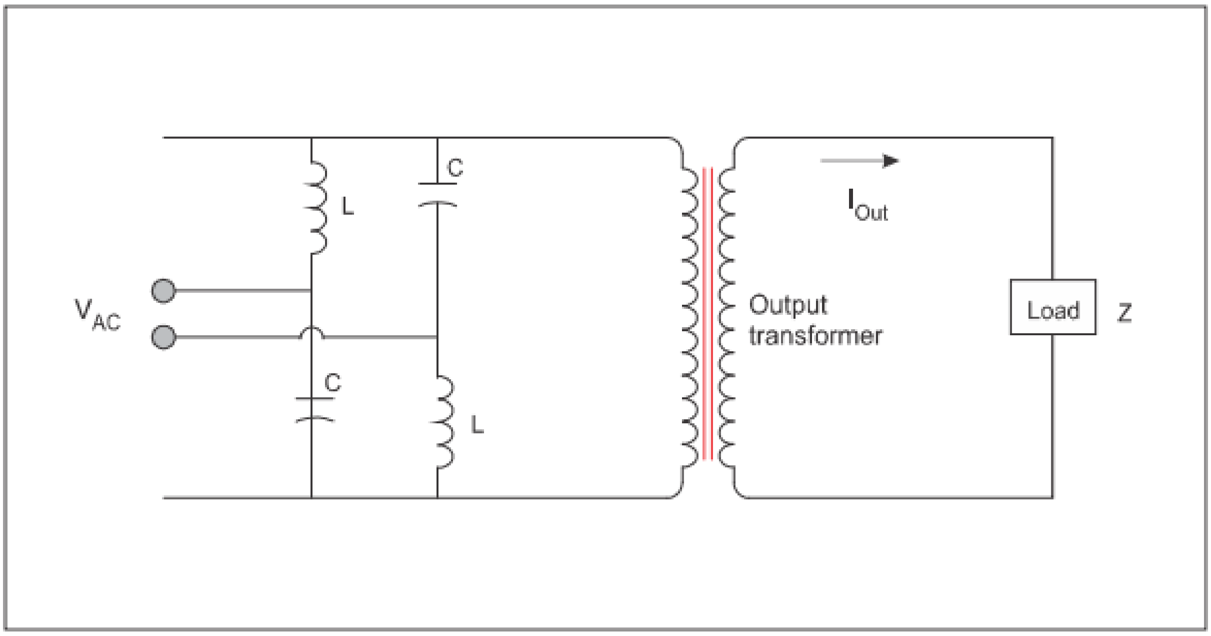

Figure 2-2. Resonant network regulator

2.4 Saturable reactor regulators

2.4.1 These CCRs use saturable reactors and a control circuit to adjust reactance and regulate current. Compensation can improve regulation under varying conditions.

2.4.2 Key points:

- Improved current regulation compared to basic resonant network designs.
- Requires correct configuration of feedback/control circuitry.

2.4.3 The saturable reactor CCR consists of two saturable reactors, a main isolation transformer, control circuitry, and an output transformer. The AC reactance of the input saturable reactors is automatically adjusted through means of a DC input current, with the result that the reactors, in combination with the output transformer, act as a voltage divider which regulates the load current. By sensing the output current from the regulator, adjustments may be made to compensate for primary voltage variations and for harmonic frequencies caused by open-circuited secondaries of isolating transformers. This compensation provides improved current regulation and prevents shortening of lamp life from above-rated secondary current (see Figure 2-3).

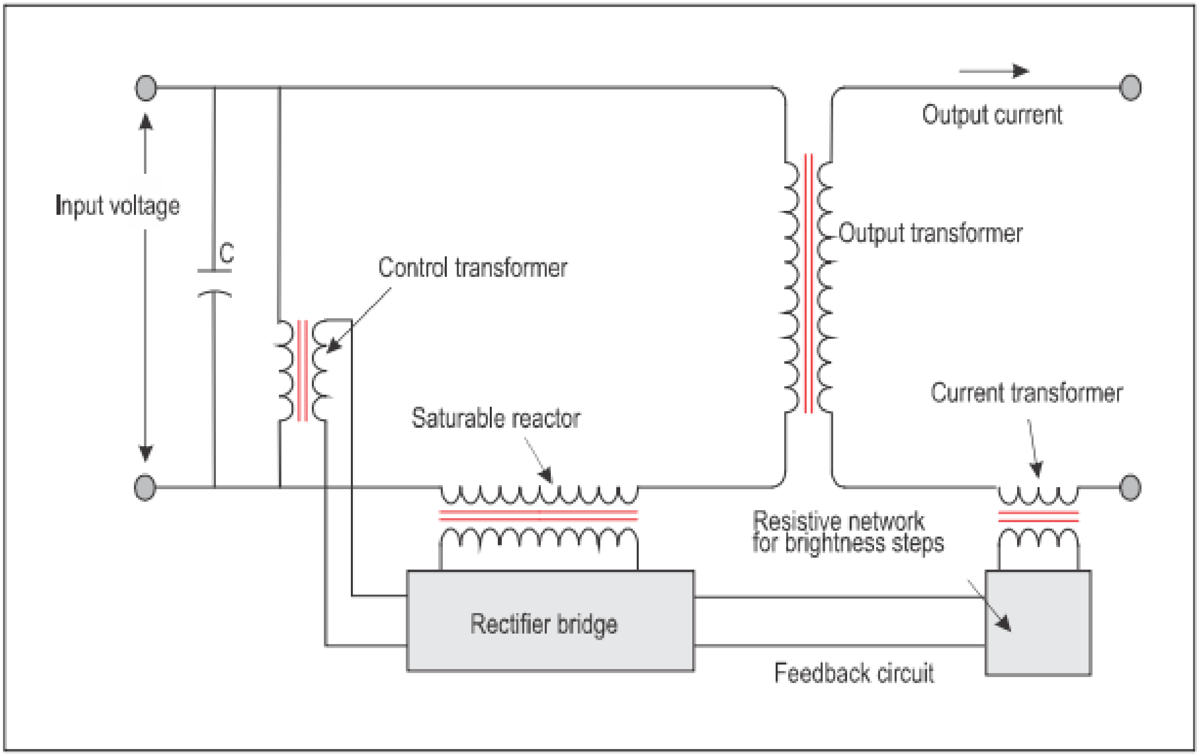

Figure 2-3. Saturable reactor regulator

2.5 Solid-state (SCR) regulators

2.5.1 Solid-state CCRs commonly use SCRs (thyristors) to control the effective RMS current by chopping the input waveform.

2.5.2 Key points:

- Fast response and compact design.
- Includes electronic protection and control functions

2.5.3 These regulators use AC solid-state circuits for controlling the transformer leakage reactance. This technique permits the use of low control levels to obtain constant current from regulators with the electrical characteristics of constant voltage, series-resonant circuits. The solid-state controls enable fast response, high power factor, and compact regulators with easy maintenance of the regulator controls.

2.5.4 As shown in Figure 2-4, the SCRs are triggered so as to "chop" the supply voltage and thereby reduce the effective RMS value of the current.

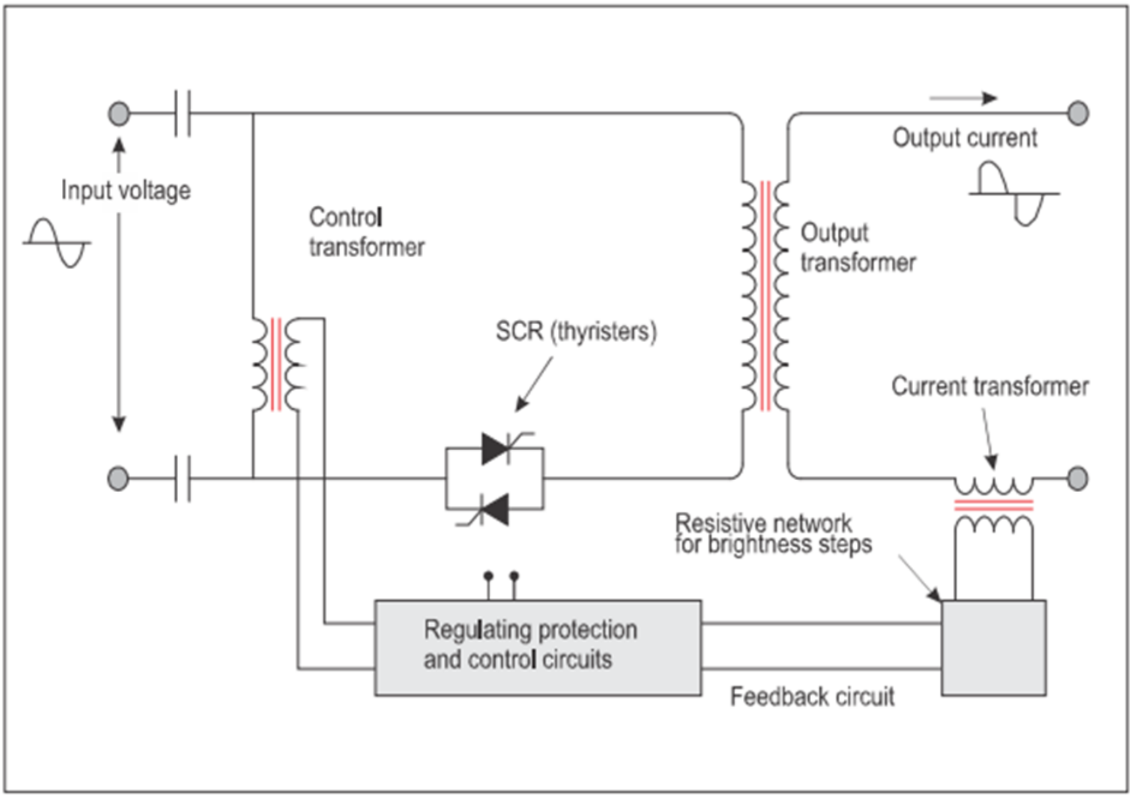

Figure 2-4. Solid state (SCR) regulator

2.6 Ferroresonant regulators

2.6.1 Ferroresonant CCRs are based on resonant network principles with design improvements to reduce harmonics and improve performance under varying loads, i.e. to overcome the disadvantages of a lack of compensation for input voltage variation and reduction of harmonics from the field circuit. The control signal is varied by means of a digital signal processor (DSP) to maintain the output current for the desired brightness step.

2.6.2 Key points:

- Typically robust and stable output.
- May be larger/heavier than some solid-state units depending on design.

2.6.3 The reaction time of the ferroresonant CCR is faster than with the solid state CCR, as the output current is regulated directly with the control circuit and control windings. As a result, the output current is not affected in any way by flashing or switching loads. The DSP and the control circuit can quickly and accurately respond to input or output changes in order to maintain a constant current. Because of the size and the customized nature of the ferroresonant transformer, however, overall package size, weight, and cost are greater than the solid state CCR (see Figure 2-5).

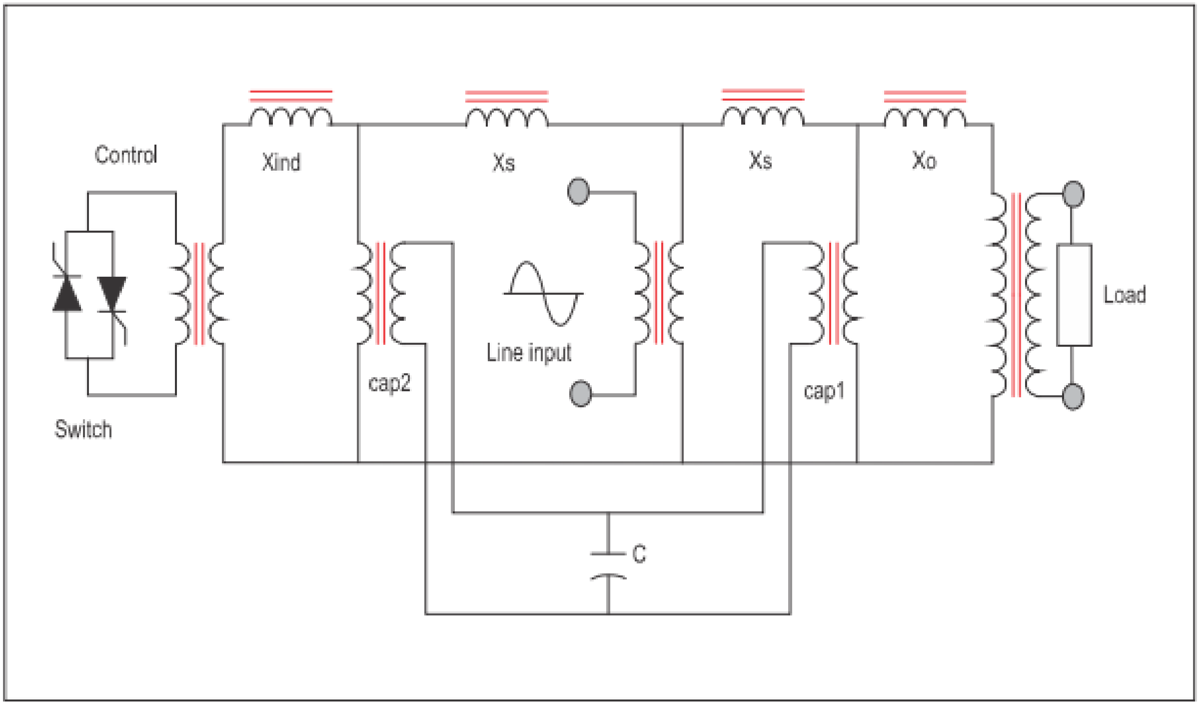

Figure 2-5. Ferroresonant regulator

2.7 Pulse width modulation (PWM) regulators

2.7.1 PWM regulators are increasingly used with LED AGL systems. Output is controlled by varying the duty cycle of a high-frequency switching waveform.

2.7.2 Key points:

- Very fast response and high efficiency.
- Low harmonics and good power factor can be achieved depending on design.
- Intensity steps may be defined by modulation rather than current level.

2.7.3 One of the most promising technologies for the development of power supplies for visual aids lighting is the use of pulse width modulation (PWM), which has gained increasing popularity for industrial variable speed drives and, if properly designed, can provide extreme accuracy and unprecedented control. It is applied for LED lighting on airfields.

2.7.4 The basic design of a PWM power circuit is with DC rectification of the incoming supply. The DC power is smoothed and filtered and then passed to an inverter stage. The inverter stage converts the DC power to an AC voltage, but at a very high frequency. The high-frequency AC is then switched with insulated gate bipolar transistors (IGBTs) to develop the desired output waveform. With a new and innovative design, power factor correction can be continuously implemented with a boost pre-regulator and a high-performance inverter. High power factors approaching unity are possible at very low loads. The output current from the regulator would be with very low distortions and with minimal harmonics.

2.7.5 With suitable firmware and hardware interface changes, the same digital signal processor (DSP) used for the ferroresonant, and SCR type regulators can be used to control the PWM CCR (see Figure 2-6).

2.7.6 The PWM design promises several advantages over existing CCR designs:

a) reduced package size, smaller than ferroresonant technology.
b) microsecond response time compared to milliseconds with SCRs;
c) lower harmonics and near unity power factor at all operating levels; and
d) Stable output is possible for input droop conditions.

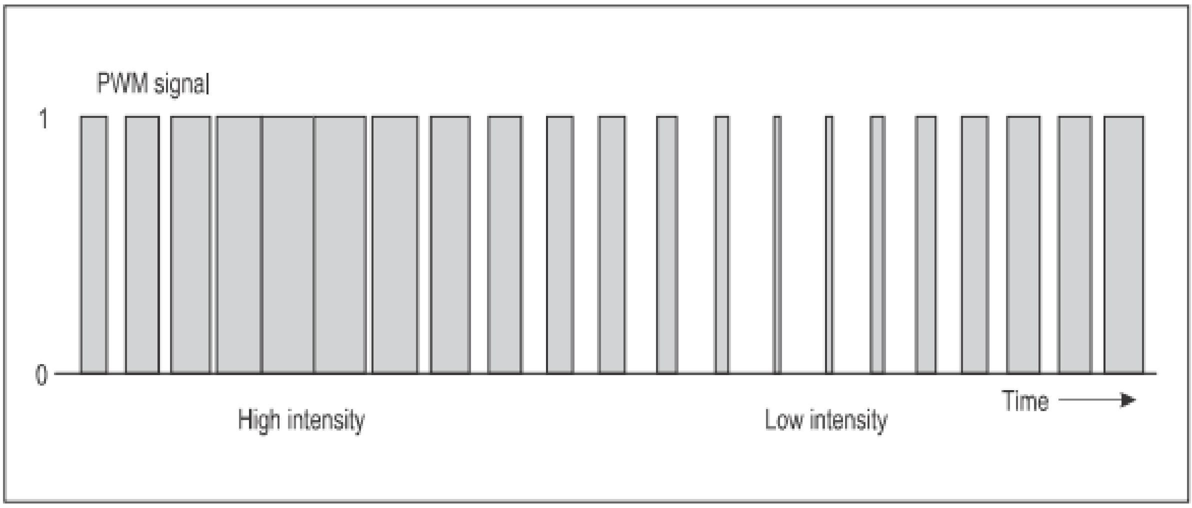

Figure 2-6. Example PWM signal (conceptual)

3. PERFORMANCE AND RATING CHARACTERISTICS

3.1 Operating Characteristics

CCRs supplying power to AGL series circuits should, as applicable, be capable of:

a) maintain a constant current output within ±2 percent for any load from one-half to full load with up to 30 percent of isolating transformers having open circuit secondaries.
b) indicate a grounding fault on the circuit while permitting the circuit to operate normally when a single ground fault prevails.
c) have a high degree of reliability and therefore have no moving parts.
d) incorporate an open circuit device that locks out the primary voltage within two seconds and requires resetting of the regulator.
e) respond to circuit changes within fifteen cycles.
f) incorporate a security device that sets the regulator out of service or assures a reduction of the current in case of an over-current.
g) provide the required number of intensity settings or a continuously variable control as required. The regulator should be designed so that the intensity setting can be changed without de-energizing the regulator.
h) electrically isolate the primary power circuit from the secondary lighting circuit.
i) dynamic characteristics which enable quick restart in case of voltage failure in accordance with the switch-over time requirements of Annex 14, Volume I, Table 8-1; and
j) operate continuously at full load in ambient temperatures between –40°C and +55°C and relative humidity between 10 and 100 percent and at altitudes up to 2,000 m.

3.2 Rating Characteristics

Typical rating parameters to confirm during assessment include:

- Power rating (kW/VA) appropriate to the circuit load and future expansion allowance.
- Secondary (output) current rating (commonly 6.6 A or 20 A, depending on the system).
- Number of current steps / intensity settings and how they are achieved (tap changer, electronic control, PWM).
- Input frequency (typically 50/60 Hz unless otherwise specified).
- Primary (input) voltage and compatibility with the aerodrome's supply and protection arrangement. (e.g. Primary voltages of 240 volts for sizes up to 30 kilowatts and 2 400 volts for sizes of 10 to 70 kilowatts. The tendency is towards a medium level of primary voltage such as 600 volt for which equipment of lesser specialization is required, such as input breakers.)

3.3 Typical current steps

3.3.1 For 6.6 A series circuits, typical current steps for 3-step and 5-step CCRs are shown below in Table 3-1. Practice may differ and LED systems may use modulation rather than current steps.

3.3.2 When considering the standard 6.6 ampere circuit, it is assumed that current less than 2.3 amperes is below the visible light level and therefore considered as an "off" condition for the pilot. A setting at 80 per cent of full brilliancy is sometimes included to save power and increase lamp life, detracting little from full visible power under normal weather conditions. For LED lighting, with PWM power supplies, the steps are defined by the degree of modulation rather than a current level.

Style	*Current step*	*Nominal output (RMS amperes)*	*Allowable range (RMS amperes)*
3-step CCR	3	6.60	6.50 – 6.70
	2	5.50	5.40 – 5.60
	1	4.80	4.70 – 4.90
5-step CCR	5	6.60	6.50 – 6.70
	4	5.20	5.10 – 5.30
	3	4.10	4.00 – 4.30
	2	3.40	3.30 – 3.50
	1	2.80	2.70 – 2.90

Table 3-1. Nominal CCR output current range (typical)

4. Protection and safety considerations

4.1 Open Circuit Protection

Open circuits in series circuits can cause loss of lighting and may damage equipment. CCRs are typically equipped with open-circuit protection to limit primary voltage and protect the regulator. Inspectors should confirm the protection method, response time, and any reset requirements.

4.2 Over-current protection

Over-current protection helps protect the CCR and associated components from abnormal conditions. Some transient conditions may cause nuisance trips; settings and coordination should be confirmed against the manufacturer's guidance.

4.3 Ground/earth fault indication

Ground/earth fault indication supports timely maintenance and reduces the risk of hazardous touch voltages. Where the CCR or associated monitoring system provides ground-fault detection, inspectors should verify functionality during commissioning tests.

5. INSTALLATION, COMMISSIONING AND INSPECTION GUIDANCE

This section provides practical prompts for aerodrome operators/contractors and CAAF inspectors when CCRs are installed, replaced, or upgraded.

5.1 Information typically required

Before acceptance/approval, the following information is typically expected (as applicable):

- Single-line diagram and wiring schematic showing CCR, primary supply, protection devices, isolation points, and monitoring.
- Load calculations and circuit details (number/type of fittings, transformer ratings, cable lengths, expected load range).
- CCR manufacturer's datasheet and installation/operation manuals (including ratings, protection features, and environmental limits).
- Evidence of EMC/EMI considerations where required (particularly for solid-state/PWM systems).
- Commissioning test plan and results, including verification of output current/intensity steps and protection functions.
- As-built drawings and maintenance instructions for inclusion in the aerodrome's technical records.

5.2 Installation checks (site)

During site inspection, confirm (as applicable):

- CCR is installed in a suitable environment (ventilation, clearances, protection from moisture/contaminants, access for maintenance).
- Mounting is stable and meets manufacturer's requirements (e.g., level/vibration isolation for moving coil units).
- Correct primary supply, earthing/bonding, and surge/protection coordination.
- Correct secondary connections to the series circuit, including insulation integrity and secure terminations.
- Correct labelling, identification, and safety signage (isolation points, hazard warnings).

5.3 Commissioning tests (typical)

Commissioning should include tests appropriate to the system. Typical examples include:

- Verification of output current at each intensity step (or modulation setting) against expected values.
- Verification of ground/earth fault indication and alarm/monitoring outputs (where provided).
- Verification of open-circuit and over-current protection operation (as practicable and safe).
- Insulation resistance and continuity checks for the circuit and associated components (per standard practice).
- Functional check of controls, interlocks, and integration with the aerodrome lighting control/monitoring system.

5.4 Records and handover

At handover, ensure the operator has (as applicable):

- Commissioning and test records.
- kUpdated as-built drawings and asset register details.
- Manufacturer’s O&M manuals and recommended spares list.
- Maintenance schedule and troubleshooting guidance.
- Evidence of staff familiarisation/training where required.

Appendix A – Inspector checklist (prompt)

This checklist is a prompt to support consistent assessment. It should be tailored to the specific installation.

A1. Desktop Review (Before Site Visit)

1. Design and Documentation Verification
    - Review submitted diagrams, single-line diagrams, load calculations, and CCR datasheet against the intended AGL circuit application.
    - Confirm CCR rating (kVA), and output current compatibility with the series circuit design load and length.
    - Verify isolation transformer ratios, tap settings, and series circuit design parameters

2. Protection & Monitoring
    - Confirm proposed overcurrent, open circuit, earth-fault, and over-voltage protection settings
    - Verify monitoring and remote-control arrangements (e.g., AGL control system) align with operational requirements
    - Ensure fail-safe interlocks, alarms, and feedback signals are included in the design

3. Commissioning Documentation
    - Review the commissioning test plan for correctness, safety, and alignment with CCR manufacturer procedures
    - Ensure test plan includes:
        - Output current regulation test
        - Intensity step verification
        - Earth-fault indication tests
        - Protection trip tests

A2. Site inspection (Installation Review)

1. Equipment Verification
    - Confirmed installed CCR model, serial number, ratings, and firmware version match approved documentation
    - Verify CCR installation environment:
        - Adequate cooling/ventilation (filters clean, fans operating)
        - Correct IP rating and enclosure integrity
        - No obstruction of airflow

2. Electrical & Protection
    - Inspect earthing and bonding of CCR chassis and associated equipment to the lighting vault/grid
    - Confirm proper protection device coordination (breakers, fuses, interlock)
    - Check for correct and safe cable termination, including:
        - Tightness
        - Insulation integrity
        - No exposed conductors
        - Correct grounding

3. Labelling and Identification
    - Verify clear labelling of
        - CCR ID and rating
        - Input/output circuits
        - Intensity steps

4. Assess & Safety
    - Confirm adequate access clearances around CCR for maintenance
    - Verify presence of:
        - Emergency stops
        - Lock-out/tag-out points
        - Hazard and voltage signage

A3. Commissioning witness (as applicable)

1. Performance Verification
    - Witness output current measurement across all intensity steps (e.g., Step 1–5/6)
    - Confirm current regulation is within manufacturer tolerance (typically ±1–2%)
    - Observe that the step transition occurs without flicker or instability

2. Monitoring & Controls
    - Verify remote control operation:
        - Correct step indication
        - Fault reporting
        - Status feedback consistency
    - Confirm monitoring outputs respond correctly (current, voltage, fault indicators)

3. Protection Function Tests
    - Verify
        - Earth -fault detection
        - Overcurrent trip
        - Open-circuit detection
        - Interlock operation
        - Emergency stop operation

4. Documentation & Handover
    - Confirm completeness of the commissioning records, including:
        - Test results
        - Calibration certificates
        - Protection setting sheets
        - As-built drawings
        - O & M manuals
    - Ensure operator briefing and handover documents are provided and signed off.