10.0 CONTROL AND MONITORING OF AERODROME LIGHTING SYSTEMS

Note: This chapter gives an overview of control and monitoring systems. In as much as the technology is moving quickly to provide yet further digital solutions, only basic examples can be given.

With regard to control and monitoring, the reader may wish to refer to: IEC 62144 - Technical requirements for Aeronautical Ground Lighting (AGL) control and monitoring systems; IEC 62143 - Guidelines for the development of a safety lifecycle methodology, and; FAA advisory AC 150/5345-56A - Specification for L-890 Airport Lighting Control and Monitoring System (ALCMS). These documents are applicable for today’s needs of midsize and major airports. They deal with all facets of design and the implementation of a control and monitoring system into A-SMGCS environment.

10.1 Apron Control Panel

Although this chapter primarily discusses the control and monitoring of lighting installed on the manoeuvring area [approach, runway and taxiway lighting] a second control system may be provided for the lighting in the apron area for such as floodlighting, apron taxiway lighting, aircraft stand taxilane lighting, aircraft stand manoeuvring guidance lights and visual docking guidance system. The graphic of this second control may be remoted to the operations/maintenance centre. It may be necessary to provide a degree of interface between this panel and the one installed in the ATS tower. Figure 10-2 shows an apron control panel as installed at Munich International Airport.

This control panel enables operation of lighting on the apron and thus facilitates the flow of aircraft from taxiways of the manoeuvring area to the gate positions. For complex aprons with numerous gates positions, provision should be made such that, for an aircraft stand taxilane, only the aircraft stand manoeuvring guidance lights for the gate intended to accept the aircraft are turned on. The lights have omnidirectional output and therefore can be seen by the pilot from a distance when following the aircraft stand taxilane lighting. Arrangement should be made such that the visual docking guidance system is also turned on at this time. As well, the apron
floodlighting may be controlled such that it is turned off or dimmed when the gate to which it applies is not in service to receive aircraft.

![Figure 10-2. Apron control panel](image)

### 10.2 Control circuitry

10.2.1 The control circuitry for aerodrome lighting provides the means of switching on or off and of changing the intensity of the various lighting systems. These controls may be manual or automatic.

10.2.2 Local manual control. The simplest control system is a switch at the power supply unit of the circuit which is operated by a person to energize or deenergize the circuit. This control method is used at some small aerodromes or some miscellaneous associated lighting circuits. A means of local control, especially at the electrical vault should be provided as an alternate control point during emergency operations.

10.2.3 Remote control. The lighting systems for larger aerodromes are complex and proper control is related to atmospheric conditions, time of day, pilot request, the positions and manoeuvring of several aircraft, and other activities on the field. Thus the selection capability of the control system is remoted [from the electrical vault] to the tower which such factors are known. Some aerodromes may have special control stations at other locations such as the operations data centre.

10.2.4 Types of remote control systems.

10.2.4.1 Several types of control systems are used for aerodrome lighting. Traditional control/monitoring systems, both military and commercial, are relay systems. Typically, as shown in Figure 10-3, cables required for these types of systems are multi-pair (50 or more pairs) cables to connect the electrical vault the air traffic control tower.
10.2.4.2 The distance between the control and electrical vault can be significant, resulting in a costly cable installation with the cable vulnerable to possible damage or failure of one or more pairs in the cable. In addition, these communications cables require separate duct systems to eliminate interference from the power cables. The traditional relay panel and multi-conductor control cable can also be simplified by using a multiplexer, which requires only one pair cable to communicate between the vault and tower (or other station). A multiplexer can also be built into a PLC system.

10.2.4.3 In the traditional control system alternating current (ac) power is often used to energize the controls. This ac power may be at the low distribution voltage or at a special voltage more suitable for the length of the control cable runs and the size of the conductor. These controls may be connected directly to the power control device from the remote control panel or by auxiliary relays to operate the control devices. Alternately, some control systems use 24 or 48 volt DC for the control voltage, especially to reduce inductive coupling between circuits. Some aerodromes
use radio signals for control, either air-to-ground for pilots or ground-to-ground for equipment located in areas not easily accessible to control circuits. These control systems should be capable of a high degree of operational reliability and should be designed to provide, as far as possible, the integrity of the lighting patterns selected regardless of control cable faults or equipment failures.

10.2.4.4 Computerized Control System. In the past decade, there has been considerable advancement in the design of control systems. Early designs involving the use of toggle switches and rotary position switches have given way to the modern Aerodrome Lighting Computer System (ALCS) consisting of Human Machine Interface (HMI) units, programmable logic controllers, remote terminal units, a supervisory (computer) system, and a communications infrastructure. As shown in Figure 10-4, most critical components are redundant with two network connections. Additional backup may be provided by means of radio ground-to-ground communication.

Figure 10-4: Aerodrome Lighting Computer System (ALCS)

10.2.4.5 Mimic diagrams. Early forms of control panel, consisting of toggle and rotary switches, required that the controller examine the physical positioning of the switch to verify
what had or had not been turned on. Mimic diagrams, as illustrated in Figure 10-5, evolved for aerodromes having complex patterns, providing an overall view of the airfield status.

10.2.4.6 Such mimic diagrams, however, were specific to individual layouts and so involved considerable cost not only for first production but also for later modification as additional lighting facilities were installed at the aerodrome. With the use of graphics software, modern installations can have the diagrams along with any control devices displayed on a touch sensitive screens as shown in Figure 10-6. Touch-sensitive screens may be of infrared, surface acoustical wave (SAW), resistive or capacitive technology.

Figure 10-5: Mimic diagram with physical controls

Figure 10-6: Mimic diagram with buttons on touch sensitive screen
10.2.4.7 An important feature of control systems for reduced and low visibility operations is a selection capability provided to ATS for turning on the facility for secondary power supply. Figure 10-7 illustrates a control module for turning the diesel electric generator upon declaration of Category 2 operations.

Figure 10-7: Utility/secondary power supply control

10.2.4.8 Data Pages. Perhaps the most significant benefit of the ALCS is that it can provide data pages with information on facility status as well as maintenance activities which had been undertaken. The historical record of this data enables refinement of preventive maintenance planning, installation improvements and budgetary forecast.

Figure 10-8: Data pages for operational performance and maintenance diagnosis
10.3 Transfer relay panel

10.3.1 For safety of maintenance personnel and to avoid conflicting operation of the controls, only one control station should be able to operate a given circuit at any time. Transfer relay panels are used to switch the operating capability from the primary control panel to the alternate control panel. To accommodate all the control circuits involved in the transfer, several transfer control panels may be used but usually a single transfer switch actuates all of the control panels. The transfer control panels and the transfer switch are usually located at the site of the alternate control panel. For the ALCS, the switch transfer can be incorporated as a button onto the monitor screen. Activating the button should bring up a dialogue box requesting identification and password.

10.4 Use of relays

10.4.1 Relay panels for long control circuits. Where control circuits are long, the voltage drop in the lines may be such that power control devices cannot be operated directly from the primary remote control panel. Even circuits which earlier operated satisfactorily may become inoperative after additional control circuits are added. To permit control at the longer distance, relays with low-current coils may be used to energize the controls of the power equipment. These relays are often assembled in panels containing several (16 or more) relays. (These relay panels are sometimes called pilot relay panels.) A relay may be provided for each control line from the primary remote control panel. The contacts of these relays control the power to the switches or controls of the power equipment functions.

10.4.2 In the case of the ALCS, communication between the control tower, operations room and electrical vault is by normally by means of a fibreoptic link which is not limited by distance, voltage drops or even electromagnetic interference.

10.4.3 Relays in the field. Some individual visual aids or short lighting circuits (aerodrome beacons, wind direction indicators, sections of obstacle lights, simple approach lighting systems, etc.) may obtain power from a lighting vault or from a local source of power. If the power is from a local source, the relay for controlling these lights is usually located at or near the light or source of power. If the control cables are long, the conductors of the control cable may need to be large to reduce the voltage drop.

10.4.4 Circuit selector relays. For series systems it is sometimes desirable to supply two or more lighting circuits from the output of a single constant current regulator. To this end, a cabinet of circuit selector relays as shown in Figure 10-9 is used. Typical applications are:
- Switching of PAPI, VASIS, and approach circuits from one approach end to the opposite end so as to reduce the number of regulators.
- To provide individual control of multiple small circuits (e.g. taxiways) which enables standardization of regulator sizes while still providing individual circuit control.
- Control of stopbars, lead-on lights and directional taxiway centerlines as part of a Surface Movement and Guidance Control System (SMGCS).
10.5 Interconnection of controls

10.5.1 Often the operations at the aerodrome are such that certain combinations of lights are always used together or other combinations are prohibited. Examples are:

a) Runway edge lights, threshold lights, and runway end lights may be operated at the same time although the power may be provided from different circuits. Normally, the edge, threshold and end lights are on the same circuit or set of circuits.

b) Runway edge lights may be operated without the runway centreline lights but if the runway centreline lights are used the runway edge lights are always energized;

c) Sequenced-flashing lights of the approach lighting system can be used only when the incandescent lights of the system are on.

d) Setting of the intensity control for a given atmospheric condition may operate the approach lighting system at one intensity step, the runway lights at another intensity step, and the taxiway lights at yet another intensity step in order to maintain a balance between the lighting systems.

e) Rapid exit taxiway centreline lights may be given individual control and an intensity level which is that of the associated runway centreline lights.

f) The control system may be designed such that the controller can obtain a combination of lighting facilities for a specific mode of operation. For example, for landing on a
particular runway, a single selection for say "Landing 31" will result in approach, runway and taxiway lighting being turned on in unison at intensity levels determined automatically in reference to visibility conditions. Similarly, runway lighting and low visibility taxiway routes may be selected from a single control device.

g) Stopbars are normally installed along with an associated system of green "lead-on" lighting. The control is such that ATC can turn on all of the stopbars for a runway and then have individual control of those giving access to the runway ends or at locations for runway crossing. When the stopbar is turned off, the associated lead on lights are illuminated to give a visual confirmation of voice instruction to proceed. The stopbar is turned back on through sensing [microwave sensors, pavement loops, etc.] of the passing of the aircraft. When the stopbar is turned back on, the associated lead-on lights are turned off. The installation at the airport may be such that the lead-on lights are automatically controlled in segments.

e) intersecting runways should not be lighted simultaneously. Only by properly interconnecting the controls and control circuits, can the desired combinations be obtained or undesired combinations prohibited with simpler operations by the controller and lesser chance of error. Each aerodrome should consider possible control interconnection combinations in relation to their installations and operating procedures.

10.6 Automatic controls

10.6.1 Some types of aerodrome lighting aids may be controlled satisfactorily by automatic controls. More often these automatic controls are used at smaller airports, but they may be used for less critical visual aids at large aerodromes especially at locations not easily connected to the control circuits. Some installations may need manual control to override the automatic control of certain lighting circuits.

10.6.2 Photoelectric controls may be used to energize and deenergize aerodrome beacons, wind direction indicators, and obstacle lights in less critical areas. The controls are usually actuated by northsky illuminance levels with switching taking place at from 600 to 350 lux for day to night transition and from 350 to 600 lux for night to day transition.

10.6.3 Time switches may be used to automatically control the aerodrome lighting at aerodromes with non-instrument capability where the visual aids are turned off after a certain hour at night to conserve energy. The switch should be of the astronomic type which is self adjusting for seasonal changes in sunrise and sunset. Thermal controls may be used to actuate heaters of some visual aids to prevent the formation or accumulation of ice, snow or condensation. These thermal controls may be obtained with fixed or adjustable control for many different temperatures.

10.7 Addressable Lights

10.7.1 Light fixtures that are controlled individually are referred to as "addressable lights". Figure 10-10 shows a typical power line carrier arrangement for addressable switching devices. Each fixture is connected to an Addressable Control and Monitoring Unit (ACMU) on the
secondary of the isolation transformer. There is an interface in the vault that sends messages onto the series lighting circuit. The ACMUs in the field receive the signals generated onto the cable by the Series Circuit Interface turning on the light and provide a monitoring response as to activation. Each ACMU is programmed with unique configuration parameters that pertain to the associated fixture.

Figure 10-10: Addressable Lights

10.7.2 Although the majority of installations use a power line carrier technology since no additional cable is required, addressable switching systems are also available using fibreoptic or twisted pair copper wire as a means for data communication. The designer must be aware, however, that each type of data communications method has its own set of design requirements.

10.8 Response Time

10.8.1 The response time of the ALCS should be such that where a change of operational status occurs, an indication is provided within 2 seconds for stopbars and within 5 seconds for all other types of visual aids.

10.9 Monitoring of aerodrome lighting circuits

10.9.1 Article 8.3 of Annex 14 states that a system of monitoring visual aids should be employed to ensure lighting system reliability. Monitoring may be accomplished by visual observations or by an automatic sensor. Visual monitoring, except for what Air Traffic Control sees and pilots report, is seldom used. Some of the monitoring of lighting systems in use consist of indicator lights which indicate only that the switches which control the circuits are turned to
ON or that one or more lights in a circuit have failed. Reliable monitoring is very desirable, but partial or incomplete monitoring can create a false sense of security. Examples are: indicator lights which respond only to switch position changes or control relay operations which do not detect a malfunctioning constant-current regulator or a grounded out lighting circuit.

10.9.2 Annex 14, Chapter 10 defines an "unserviceable" light unit as that for which there is a loss of output such that the main beam average intensity is less than 50 per cent of the value specified in the appropriate figure in Appendix 2. For light units where the designed main beam average intensity is above the value shown in Appendix 2, the 50 per cent value shall be related to that design value. One state stipulates a failure as reduction below 70 percent of the required intensity. In the case of regulator monitoring systems, it is not yet possible to indicate a failure which is an intensity reduction and therefore monitoring is with respect to total loss of output due to opening of a lamp filament. Similarly, a regulator monitoring system cannot detect other modes of failure such as obscuring by grass, snow or rubber deposit and daily field inspection remains a necessity.

10.9.3 Light fixtures designed with an LED source(s) do not have the same failure mode as a light unit using an incandescent lamp. In brief, there is no filament that open circuits so as to cause a measureable change in circuit characteristics. The LED light design, therefore, should have an ability to provide an open circuit (fail-open) at the secondary of the AGL transformer, or draw zero current on a constant voltage circuit. This is particularly required if the fixture is to be retrofitted into an existing circuit with monitoring means.

10.9.4 The ideal monitoring device for aerodrome lighting would be capable of measuring the intensity of each light, however such monitoring is neither practical nor possible. The design of monitoring devices is usually with respect to quantities that can be measured, as for example the presence or absence of current in the lamp circuit.

10.9.5 The lighting systems are monitored for the following fault conditions:

- Loss of ac input power to the constant current regulator
- Shutdown of the regulator due to operation of protective circuits
- A 10 percent or greater drop in the volt-amperes (VA) delivered to the series circuit.
- Failure of the regulator to deliver the output current that corresponds to the brightness step selected
- Failure of a preset number of lamps in the series circuit.

10.9.6 Those fault conditions which pertain to total circuit failure -- that is, loss of the lighting to aircraft -- are alarmed to the control tower. Those faults that are related to maintenance criteria, such as failure of a preset number of lamps, are indicated to an operations centre or to the electrical vault. Where a lighting system is composed of two or more circuits, the failure of one circuit may be alarmed only to the operations centre.

10.10 Classes of monitors

10.10.1 Monitors may be classed as active or passive. Active monitors take a predetermined action when a specific condition is sensed or at a selected time after the condition occurs.
Examples of monitors in this class are the primary source voltage sensors which automatically start the secondary engine-generator set and transfer the load when the primary power source fails, or the high intensity time limit control which automatically resets to a lower intensity step and sounds a buzzer and/or energizes an indicator lamp after the lights have been at full intensity for 15 minutes.* Passive monitors provide a signal such as an indicator lamp or buzzer when a predetermined condition occurs and does not change any of the systems operations. A human operator must evaluate the meaning of the signal and take appropriate action. Examples of passive monitoring are the sequence flashing lights monitor which alerts when a preselected number of lights is inoperative, or the indicator lamp which shows that specific circuits are energized and operating.

* Automatic resetting of the intensity is not desirable since the change could be made when a pilot is in a critical part of his approach.

10.11 Monitor override controls

9.11.1 Often controls or procedures which can be used to override or circumvent the action of the monitor are provided. By activating a special circuit or resetting a control, the operator can maintain the systems operation without change for new or indefinite time period. The signal indicating the monitor's response may be provided during the override operation to keep the operator informed that the system is in an undesirable operating status. An example is to reset the timer to full intensity operations at the beginning of each approach in low visibility conditions to ensure that the lights will not automatically be changed to a lower intensity during the approach.

10.12 Insulation Resistance Monitoring System

Constant current regulators can be provided with an insulation resistance monitoring system which enables real time monitoring of the circuits as well as the generation of statistical reports.

10.13 Radio Control of Aerodrome Lighting (ARCAL)

10.13.1 Radio signals from aircraft to control aerodrome lighting systems have been used, to a limited degree, at smaller aerodromes for several years. This control method has several advantages in that it permits the pilot to select the light intensity of his choice, eliminates the need for costly control cables, and conserves power by having the lighting system deenergized when not needed. Radio controls for air-to-ground, ground-to-ground, and a combination of air-to-ground and ground-to-ground systems are available. Ground-to-ground control is used mostly when cable control circuits are not available and are not practical to install. Ground-to-ground control should be used only temporarily until cables can be installed or permanently especially to remote locations.

10.13.2 Aircraft Radio Control of Aerodrome Lighting (ARCAL). For ARCAL or Air-to-Ground operation only a receiver and decoder are installed on the airport. This form of control has been used to control runway edge lights, taxiway edge lights, simple approach lighting systems, visual approach slope indicator systems, as individual systems or in predetermined
combinations at uncontrolled aerodromes or at other aerodromes during periods when traffic control is not in operation. Obstacle lighting should not be radio controlled.

10.13.3 The actuating signal may be provided by a specified short series of clicks accomplished by keying the microphone of an aircraft communications transmitter as indicated in Table 10-1. At the end of a prescribed period [i.e. 15 minutes], the lights will be either turned off or returned to a preset brightness depending on the selected operating mode. The system may be recycled at any time for another 15 minute period at any intensity step desired by keying the microphone the appropriate number of times. Except for RILs with 1 or 2 steps, the lighting systems may not be turned off by radio control before the end of the 15-minute cycle.

10.13.4 The ARCAL is tuned to a single frequency in the range of 118-136 MHz, which is assigned civil aviation authority. Whenever possible, the Common Traffic Advisory Frequency (CTAF) is used for radio control of airport lighting. The CTAF may be UNICOM, MULTICOM, FSS, or tower frequency and is identified in appropriate aeronautical publications.

10.13.5 Interfacing the Radio Control with the Lighting Systems.

10.13.5.1 The output of a single airport-owned radio controller is usually connected to the control inputs of several lighting systems. The radio controller may be directly connected to the lighting systems, or an interface box may be used to reduce the load on the radio controller’s output relays or to allow additional switching capabilities. The following paragraphs discuss the design considerations when interfacing a radio control with several lighting systems.

10.13.5.2 The radio control system is configured so that the runway lights are on whenever the other lighting systems serving the runway are on (except during day operations. When a runway has approach lights that are radio controlled and edge lights that are not, then the edge lights are left on at a brightness selected according to the anticipated weather conditions during the hours of night operation. If the runway lights are radio controlled and the approach lights are not, then the approach lights may be left off or at a preselected brightness. The approach lights must never be on while the runway lights are off.

10.13.5.3 On runways where the approach lights and the runway lights are both radio controlled, the intensities of both systems are increased or decreased simultaneously by the radio control.

10.13.5.4 While the radio control equipment is equipped with three intensity settings, airport lighting systems may have one, two, three, or five intensity steps. Table 10-1 gives guidance on how to interface the radio control with the intensity steps of the airport lighting system. For example, a lighting system with five intensity steps would be connected so that three clicks of the microphone would energize brightness step 1 or 2, five clicks would energize step 3, and seven clicks would energize step 5. The airport authority may select either step 1 or 2 for the lowest brightness setting, depending on the background lighting at the airport.

10.13.5.5 On systems where the intensity is automatically controlled by a photocell or other means, the radio control will simply energize the system and the intensity will be selected automatically by the photocell.
10.13.5.6 RIL systems may have one or three intensity steps. The radio control of RIL should be tailored to the equipment used and the needs of the facility. The common practice is to have the RIL turned off at the lower intensities and energized at the higher intensities.

10.13.5.7 When air-to-ground radio control is used at night, the lighting system may not be energized for long periods of time. During these “idle” periods, the airport beacon, obstruction lights, and any other lighting systems that are not radio controlled will continue to operate while the radio-controlled systems are off. As an option, the runway edge lights may be left on a low intensity step. (The step selected will depend on local conditions.) If the runway lights are left on during idle periods, other lighting systems may also be left on at a pre-selected intensity.

10.13.5.8 Since the runway and taxiway edge lights, approach lights and lighting for taxiway signs are not normally needed during the day (except during restricted visibility conditions), the radio control system may be configured with a day mode that energizes only those lighting systems which are useful during the day. Using this control mode, however, means that daytime instrument flight rule (IFR) procedures associated with the deactivated lighting systems may not be used. The day mode may be selected automatically by means of a photocell or manually by use of a switch. In areas with heavy voice traffic on the frequency used by the radio controller, there may be nuisance activation due to three random microphone clicks in a 5-second period. If this is a problem, the three-click setting on the radio control may be bypassed for daytime use.

10.13.5.9 Other control devices, such as interlocks, photocells, and switches, may be used to provide flexibility of the radio control system under differing operational conditions. For runways with lighting systems on both ends of a runway or at airports with more than one runway, it may be desirable to incorporate a manual switching system to allow the airport operator to choose which lighting systems will be energized by the radio control. This will permit the pilot to activate only those lighting systems that serve the active approach runway and taxiways.
Table 10-1. Interface of Radio Control with Airport Visual Aids.

<table>
<thead>
<tr>
<th>Lighting System</th>
<th>Number of intensity steps</th>
<th>Intensity step selected per number of microphone clicks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 clicks</td>
<td>5 clicks</td>
</tr>
<tr>
<td>Approach Lights</td>
<td>2</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>1 or 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edge Lights</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Intensity</td>
<td>1</td>
<td>On</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Low</td>
</tr>
<tr>
<td>Medium Intensity</td>
<td>5</td>
<td>1 or 2</td>
</tr>
<tr>
<td>High Intensity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxiway Edge Lights</td>
<td>1</td>
<td>On</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Low</td>
</tr>
<tr>
<td>Runway Centerline,</td>
<td>5</td>
<td>1 or 2</td>
</tr>
<tr>
<td>Touchdown Zone Lights.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxiway Centerline</td>
<td>3</td>
<td>Low</td>
</tr>
<tr>
<td>Lights</td>
<td>5</td>
<td>1 or 2</td>
</tr>
<tr>
<td>RIL</td>
<td>1</td>
<td>Off</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Off</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Low</td>
</tr>
<tr>
<td>PAPI **</td>
<td>3</td>
<td>On</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>1 or 2</td>
</tr>
<tr>
<td>Wind Direction</td>
<td>1</td>
<td>On</td>
</tr>
<tr>
<td>Indicator</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* A photocell may be installed on the system to allow the 5 click setting during daytime operations.