light:guard System Description

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contents.

abbreviations.

AVV	Allgemeine Verwaltungsvorschrift zur Kennzeichnung von Luftfahrthindernissen General administrative regulation for marking of aviation obstacles
ADLS	Aircraft Detection Lighting System
EEG	Erneuerbare-Energien-Gesetz Laws on Renewable Energies
LCU-T	Light Controller Unit - Transponder Version
IF	Interface
MLAT	Multilateration
OEM	Original Equipment Manufacturer
QUAD	Quantec Area Distributor
SCADA	Supervisory control and data acquisition
WAN	Wide Area Network
LTE	Long Term Evolution or 4G wireless broadband
WTG	Wind Turbine Generator
LGR	Light:Guard Receiver

background.

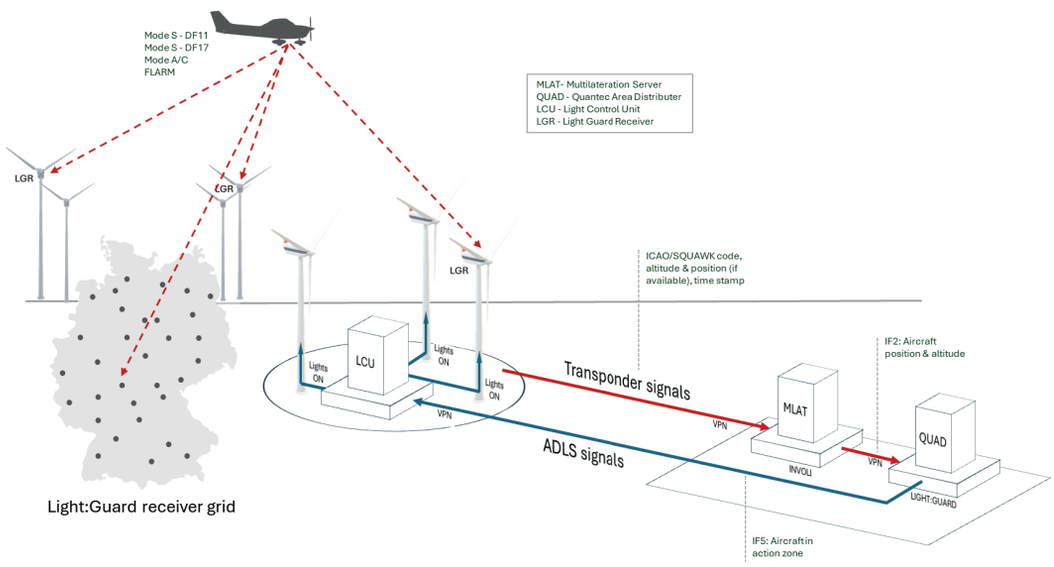
German authorities stipulate in the EEG amendment of 2019 the use of Aircraft Detection Lighting Systems (ADLS) for all wind turbines to reduce visual disturbance during night time and hereby increase acceptance of the public to the wind energy sector.
All future and already erected wind parks need an assessment if all requirements according to the regulations apply. If this is not the case the prerequisites for the obstruction lights as well as for ADLS control must be fulfilled until the current deadline 31st December 2024.
The regulation is described in the Allgemeine Verwaltungsvorschrift zur Kennzeichnung von Luftfahrthindernissen (AVV).
According to its latest version of April 24th 2020, the ADLS obligation can also be fulfilled with devices that use aircraft transponder signals. For further details see reference /1/ BAnz AT 30.04.2020 B4 - Allgemeine Verwaltungsvorschrift zur Kennzeichnung von Luftfahrthindernissen vom 24. April 2020.

light:guard is a transponder based ADLS system.
It detects transponder signals from flying objects and sends signals to wind farms as soon as an aircraft enters a specific range around them. The system starts operating with the begin of the civil dawn and ends operating with the begin of the civil dusk at the locations of the wind farms connected to it.
At dawn, if there is no aircraft detected around a specific wind farm, the systems suppresses the obstruction lights of the turbines. During night, lights are off as long as no aircraft is around the wind farm.
When the systems detects an aircraft in the considered target area around the wind farm, it sends a light-on command to the wind farm and obstruction lights are turned on. Also in the case that an aircraft is detected but its position cannot be determined, lights will be turned on for safety reasons. The receivers detect signals coming from Mode S, Mode A/C or FLARM transponders. The received signals at the receivers get a time stamp with a precision of nanoseconds and information about the receiver position.
The data is sent via VPN to the Quantec Data Center using an existing ethernet connection or via LTE. At the Data Center, if enough receivers detect the signal of the same aircraft, its position will be determined by the MLAT algorithm using the multilateration method. A separate unit at the Data Center, the Quantec Area Distributor (QUAD) compares the positions of the received aircraft transponders and compares them with the positions of the wind farms.
At the wind farm, the well tried Light Control Unit receives the lights-on/off-information from the QUAD and gives the corresponding command to the obstruction lights or to the centralized SCADA system.
The system can be used with obstruction lights equipped with infrared lights. The system operates according to AVV regulations by only sending activation and deactivation commands to obstruction lights visible for human eyes.

components.

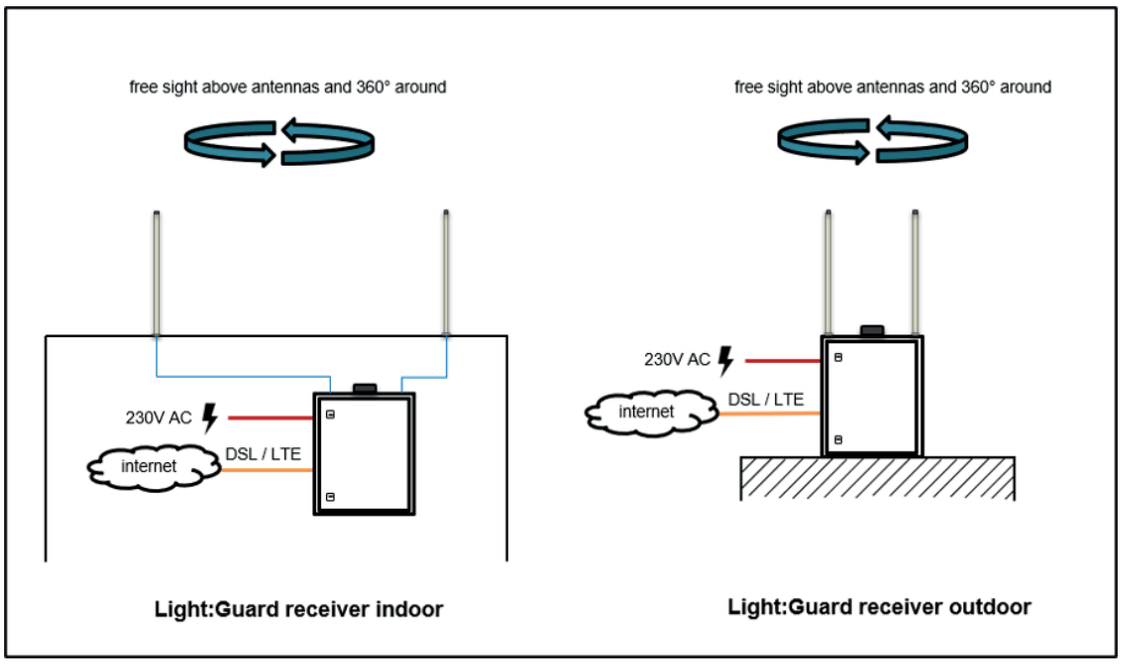
The light:guard system consists of the following components:

- Light:Guard receiver
- MLAT server
- Quantec Data Center
- QUAD: Quantec Area Distributor
- GUI: Graphical User Interface
- LCU-T: Light Control Unit - Transponder version



The sketch above shows the basic principle of the light:guard system.

The Light:Guard receivers are stainless steel cabinets with IP66 protection class and the capability of outdoor installation. The receivers detect radio signals on the 1090 MHz frequency and include two modules and two antennas each to guarantee redundancy. Each receiver is connected to a combined GPS and LTE antenna and it is optionally also able to detect FLARM signals (868 MHz frequency).
There are several possibilities for the receiver installation: on roofs of building, at radio masts, in the nacelle of wind turbines or on their roof, etc., the only conditions are free sight for the antennas and power supply for the cabinet.



For a detailed description of the receivers see references /2/ Datasheet Light:Guard Receiver and /3/ Light:Guard Receiver Circuit Diagram

MLAT server.

The server receives all the messages from the sensors and computes multilateration. The result of MLAT is then sent to the QUAD via a WebSocket protocol. Multilateration is the technique of estimating the position of an aircraft using the different time of arrival of the same radio message at different receivers, and is a well known and understood technique used in aviation.
In essence, multilateration optimizes the estimated position of an aircraft by minimizing the error between measured and computed time of travel of the radio signal.
Because the time of emission of the radio signal is unknown, it has to be estimated along the 3 spatial dimensions, hence a conventional multilateration algorithm requires that at least 4 receivers detect a message to compute a 3-dimensional position estimate.

r	Distance to measuring station
xi, yi, zi	Position of the measuring station
x, y, z	Position of the aircraft
tE	Time of emission
tA	Time of arrival
c	Propagation velocity

QUAD

The Quantec Area Distributor (QUAD) is a software based component which receives a high amount of aircraft transponder data, filters out non relevant information and compares the remaining data with the positions of the controlled wind farms in order to send a lights-on command to the wind farms where an aircraft has entered the corresponding action range.
Reference /5/ QUAD Description offers a detailed description of how the QUAD works.

GUI

The Graphical User Interface is a tool that enables external users such as the military authorities access to the ADLS control system. Users can log in with user name and password, view flight tracks in a specific area and enable or disable the ADLS system.
See reference /6/ Light:Guard Graphical User Interface for further information.

safety concept. interfaces. LCU-T.

LCU-T

The LCU-T is the internal control unit for the wind farm obstruction lights and receives the signals to control the lights. The unit controls the
obstruction lights over an interface that has been developed individually for each obstruction light manufacturer. The light control can be distributed to up to three different networks inside the wind farm.
Thus it is possible to control mixed wind farms consisting of wind turbines of different manufacturers using a single LCU-T. The LCU-T can receive signals from active radar systems or from transponder based detection systems.
For detailed information see reference /7/ Data sheet LCU-T.

Interfaces

The main interfaces in the light:guard system have been explicitly defined and are described in separate documents:
/8/ IF2: Interface between MLAT-Server and QUAD
/9/ IF3: Interface between QUAD and GUI data interface protocol
/10/ IF4: Interface between GUI and QUAD data interface protocol
/11/ IF5: Interface Quantec Sensors LCU-T control interface protocol

Safety concept

The ADL system has a general safety concept for normal operation and a fallback process for other cases such as insufficient data or communication loss.
The system uses different determination principles to control the obstruction lights and they activate different control conditions in the data center. For a detailed description of the safety concept see: reference /13/ Light:Guard Detection and Safety Specification

references.

/1/ BAnz AT 30.04.2020 B4 - Allgemeine Verwaltungsvorschrift zur Kennzeichnung von Luftfahrthindernissen vom 24. April 2020
/2/ Datasheet Light:Guard Receiver
/3/ Light:Guard Receiver Circuit Diagram
/4/ INVOLI System
/5/ QUAD Description
/6/ Light:Guard Graphical User Interface
/7/ Data sheet LCU-T
/8/ IF2: Interface between MLAT-Server and QUAD
/9/ IF3: Interface between QUAD and GUI data interface protocol
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/12/ Light:Guard Detection and Safety Specification