Design and Simulation of Airfield Lighting System Using 8 Luminaire in Airfield Lighting Laboratory at Politeknik Penerbangan Surabaya

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Abstract. Airfield lighting system (ALS) provides visual reference to aircrafts during airport operation. In ALS equipment, constant current regulator (CCR) feed a luminaire circuit supplied through isolation transformer. Luminaire circuits are a large number of lamps which organized in serial circuit and connected to CCR that supply energy to the lamps. Modeling the component is needed to simulate ALS including of constant current regulator, underground cables, isolation transformer, and lamps. This simulation is useful to study ALS behaviour and predict their response to electrical systems and future technological changes. This paper present circuit design and simulation of ALS using power simulator (Psim) software. The simulation results are observed in maximum brightness condition of the CCR. The CCR measurement results for this condition are 6.63 Ampere current output and 5kV voltage output. It has been observed that the designed system has been succesfully implemented to airfield lighting system circuit according to the component specification.

Keywords: airfield lighting system, constant current regulator, isolation transformer, underground cable, brightness, luminaire circuit, power simulator

1. Introduction

The purpose of monitoring and controlling in airport lighting system is to envolving the airport capability and improving airport efficiency in operation. This purpose could improve the safety in the airport daily operation and aircraft movement. Airfield lighting system are used to control the runway, giving visual reference for the aircraft in speed and center alignment when aircraft approaching, landing and taxiing operations [1].

Airfield lighting system is designed in order to meet latest ICAO (International Civil Aviation Organization) and FAA (Federal Aviation Authority) recommendation to guarantee safety of airport operations. Airport usually using switching device to control the airfield lighting systems [2].

Airport lighting system (ALS) give visible information to the aircraft. This system consist of luminaire to aircrafts during of approaching operation, landing operation and taxiing operations. The ALS systems has 5kV series circuits. The size cable are 2x6 mm² XLPE insulated copper underground cable. ALS equipment with constant current regulator (CCR) supply luminaire by means of isolation transformer. Constant current regulator are 5kV variable voltage source close to the airport power supply which provide tunable rms according to brightness requirement. These regulator modify the
supply voltage to maintain rms current required and ensure circuit continuity even in case beacons failure (Fig. 1).

Constant current regulator (CCR) standard has power rating 4 kilo volt ampare, 7.5 kilo volt ampare, 10 kilo volt ampare, 15 kilo volt ampare, 20 kilo volt ampare, 25 kilo volt ampare, 30 kilo volt ampare, 50 kilo volt ampare and 70 kilo volt ampare using standard current rating of 6.6 Ampere (a current rating of 20 Ampere is used for ALS system with capacity power above 30 kilo watt). The capacity of current have five steps brighntess (6.6 ampere, 5.2 ampere, 4.1 ampere, 3.4 ampere and 2.8 ampere or 20.0 ampere, 15.8 ampere, 12.4 ampere, 10.3 ampere and 8.5 ampere). Luminaire are visual guideline for pilots. The luminaire pattern, luminaire intensity, luminaire color and luminaire direction of light brightness and light emission are varied according to their equipment (airfield lighting or grund lighting system), precission approach path indicator (PAPI), runway lighting system (RLS) and taxiway light and guidance signs.

They luminaire are generally divide into high and low intensity luminaire. This luminaire has capacity power ratings above and below 150 kilowatt. The luminaire are used for airport lighting, precission approach and runway lighting and for taxiway lights and guidance signs.

The quantity of luminaire are from 10 up to 300 in small and large airport. They use approximately about \( N \text{ 10 to 300 at Fiq.1.} \) Isolation transformer break up CCR and luminaire into primary and secondary equipment. The system provide connection of the series circuit when there are broken in luminaire (serve luminaire to still operate) and break up luminare from the over voltage of the primary circuit. Whe luminaire in failure, the transformer keep circuit connectivity but operate in saturation condition because they running in open circuit at series circuit rated current. This condition know in airport lighting system (especially in isolation transformer system) because this condition depend on the CCR operation condition and will cut down for airport lighting sytem power rating quality [3].

1.1. Constant Current Regulator Modelling

Constant current regulator accept alternating current input supply and give an variable root means square current \( I \) depend to condition of five steps brightness. Nowadays, constant current regulator used sequence control with ferro-resonant transformer to serve variable output current. Present day, pulse width modulation (PWM) system used to control the system by using thyristor or IGBT because this system more reliable than using transformer. Figure 2 draw the common block diagram of constant current regulator using a PWM IGBT system to control the current.
Fig. 2. Constant current regulator block diagram.

Constant current regulator consist of an input filter circuit to control electromagnetic emission levels and reduce harmonics element that produced by the system, a PWM IGBTs power module to produce sinusoidal output voltage, a control circuit, a power transformer to regulate the output voltage and break up the constant current regulator from the series circuit and a transformer connected to the secondary windings of the transformer to control the current feedback signals to the circuit. Control regulator consist of a back up power supply which is automatically supplied power in when main power module broken, output circuit consist of an inductance which regulate the PWM carrier frequency and a capacitor circuit to control power transform and reduce the harmonics. Constant current regulator are completed with earth fault sensor and light arrestor connected to the output circuit and coupled to an grounding earth bar.

IGBTs is controlled with signal using pulse width modulation method. This signal has carrier frequency from 5 to 8 kilo Hertz and sinusoidal line frequency modulation). The combination signal produce different duty cycle according to the reference signal [4].

1.2. Underground Cable Modelling

ALS system are single phase circuit using cables with size ranging from 6mm² to 8 mm². It is installed in underground bus duct. The length of of ALS is smaller than 10 kilometres and the shortest length is greater than 40 kilometres. ALS system using frequencies about 2.5 kilo Herts (Fig.3) [4].

Fig. 3. Equivalent circuit of airfield lighting system
In this model, cable conductance is neglected and the value of Resistance (R), inductance (L), and capacitance (C) are defined from the value parameters of \( R_{eq} \), \( L_{eq} \), \( C_{eq} \) and the length value \( D \) from cable

\[
R = \frac{R_{eq}}{\text{length}} D \\
L = \frac{L_{eq}}{\text{length}} D \\
C = \frac{C_{eq}}{\text{length}} D
\]  

Parameter values are defined from the type of cable and the datasheet of cable.[2]

2. Methodology

Airfield lighting system will be implemented in Airfield Lighting Laboratory at Politeknik Penerbangan Surabaya. This system is designed by using Power Simulation Software.

2.1. Airfield Lighting System Design

Airfield lighting system and general circuit using Power Simulator software consist of constant current source according to the specific brightness, underground cables, isolation transformer and beacon/luminaire. The circuit can be shown in figure 4.

![Fig. 4. Airfield lighting system using 8 luminaire.](image)

The system in fig.4 use output voltage for CCR in step 5 brightness. In this brightness the output voltage of CCR used to supply luminaire through underground cable and isolation transformer. Underground parameter given by AGL system component. The value for this parameter are \( R_x = 3.98 \Omega/km \), \( L_x = 0.547 \text{ mH/km} \) and \( C_x = 0.126 \mu\text{F/km} \). The length of underground cables for this system (Airfield Lighting Laboratory) are about 300 m. The connection of isolation transformer for each luminaire can be shown in fig. 5.
2.2. Isolation Transformer Parameter

Isolation transformer has different parameter according to specific load. The load for this isolation transformer are 45W, 60W, 150W and 200W. The parameter of isolation transformer for specific load can be shown in table 1.

| Manufacturer | P (W) | Winding parameter | Core parameter | Per unit (pu) | Io(A) |
|--------------|-------|--------------------|----------------|---------------|-------|
| TR 45 W      |       |                    |                |               |       |
| No.1         | 45 Watt luminaire for taxiway lighting and guidance signals lighting | 0.1871 | 0.3701 | 176.51 | 1.101 | 1,112 | 0.3471 |
| TR 60 W      |       |                    |                |               |       |
| No.2         | 60 Watt luminaire far from series circuit | 0.2812 | 0.8492 | 327.61 | 1.401 | 1.201 | 0.3212 |
| TR 150 W     |       |                    |                |               |       |
| No.1         | 150 Watt luminaire for Papi, Rls, and Als | 0.2812 | 1.191 | 693.81 | 1.801 | 0.9061 | 0.2861 |
| TR 200 W     |       |                    |                |               |       |
| No.3         | 200 Watt luminaire for Papi, Rls, and Als | 0.3011 | 1.712 | 650.01 | 1.801 | 1.151 | 0.3381 |

Isolation transformer has a different parameter according to power capability. This parameter show in table 1 including of winding parameter and core parameter.

3. Results and Discussion

Simulation results are obtained from Power Simulator Software (PSIM) tools. The result of voltage and current of CCR can be shown in following figure below. The condition of voltage and current are carried out from maximum CCR step brightness (step 5 brightness).
From fig. 6, the current value for CCR is 6.63 A. Its current flow to the circuit when the brightness of the CCR is maximum. There are 5 step brightness in CCR equipment. Each steps has different current rating. Current simulation result is equal to the specification of CCR for 5 steps brightness.

CCR voltage rms is 5 kV according to figure 7. This high voltage is needed to transmit electrical power in long distances to reduce losses during transmission. Luminaire (runway lighting system, PAPI, taxiway light, guidance sign) is placed far away from CCR, so need a high voltage to supply luminaire in order to minimize the losses.

Luminaire 1 is located in taxiway lights. Luminaire 2 is located in guidance signals. They are used 45W isolation transformer rating (TR45W). Voltage rms values is 219.4 Volt in luminaire 1 circuit and luminaire 2 circuit.
Luminaire 3 is located in signal areas. Luminaire 4 is located in signal panels. They are used 60W isolation transformer rating (TR60W). Voltage rms values is 407.5 Volt in luminaire 3 circuit and luminaire 4 circuit.

Luminaire 5 is located in airfield lighting system (ALS) and precision approach path indicator (PAPI). Luminaire 6 is located in runway light systems (RLS). They are used 200W isolation transformer rating (TR200W). Voltage rms values is 808.5 Volt in luminaire 5 circuit and luminaire 6 circuit.

Luminaire 7 is used in airfield lighting system (ALS) and precision approach path indicator (PAPI). Luminaire 8 is used in runway light systems (RLS). They are used 150W isolation transformer rating (TR150W). Voltage rms values is 862.2 Volt in luminaire 7 circuit and luminaire 8 circuit.
4. Conclusion

Simulation has been carried out using Power Simulation (PSIM) software. From the simulation results, it is obtained that proposed design can be applied to airfield lighting system in AFL laboratory at Politeknik Penerbangan Surabaya. The system using 8 luminaire component in lamp. Each luminaire supplied different part in airfield lighting system. They are taxiway lights, guidance signals, signals areas, signal panels, runway light system and precision approach path indicator. The currents is equal to every part because the circuit is in series connection with constant current. The voltage values are different according to power capacity form isolation transformer parameter rating. CCR rms voltage is 5kV when supplied all of the circuit. CCR rms current is 6.63A when connected to airfield lighting system circuits. This CCR voltage and current output are produced from circuit in maximum brightness step of the system (5 steps brightness). In this paper used 5 steps brightness for analysis and simulation.

References

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