Work Analysis of Constant Current Regulator BF 1200 With Current Loop and Gauss Jordan Method as Learning Media for Cadets

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ABSTRACT

Runway lights at the airport are 1-5 km in length, which always connected in series so the pilots look the same bright lights from the beginning of runway until the end of runway. The same bright lights will be on if runway lights connected in series and every lamp obtains the same current flow. The device used to manage every runway in receiving the same current is Constant Current Regulator. Each light is installed a transformator by comparing of primary winding : secondary winding is 1:1[1] so if there is a while other lights that connected in series are " that will be analyzed how it works with series resonant principle. It can be proven that the basic CCR briefly connected then the magnitude of current is constant, although it is added by compensator, it is not a matter how much the value of load resistance (runway lamp) will still evoke current load. Compensator will carry out the best function if its reactance is as great as reactance. By using current loop and Gaus Jordan methods have found the similarity which reveals the relation between the current with load and can be stated that is not a matter how the load resistance is, will still flow the current load at constant value. Therefore, Constant Current Regulator has changed the constant voltage power supply to be a constant current power supply [1]. The aim of this paper is to define to the cadets about the application of the series resonance theory (voltage resonance), a high voltage producing from this series resonance will be flowed into electrical circuit at runway lights with constant current in accordance with the desired brightness. The learning kit for cadets is a series resonant experiments with static renance circuit with an efficiency up to 90 percent.
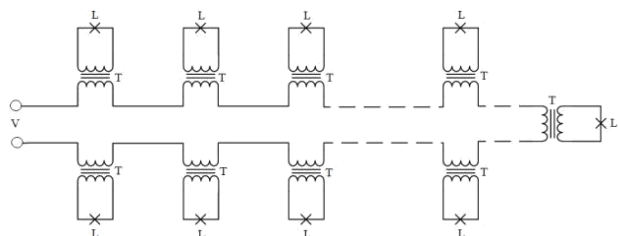
Keywords: *Constant Current Regulator, Current Loop Method, Gauss Jordan Method*

1. INTRODUCTION

Resonance electrical circuit is rarely utilized in electrical power, therefore the learning for cadets using the theory of resonance series for supplying the runway lights equipment will be written in this paper. Resonance series is voltage resonance, and a high voltage in thousand volts (4.000 Volt and above) in inductor side will be flowed to runway lights where runway lights are connected in series so that it obtains the same light intensity along the runway [4]. The aim of light installation in series is to obtain the same current in each runway lamps. If we connect the lights in parallel, then the end of the last light will be dim, because there is voltage drop in runway cable that connecting the lights (regularly using cable FLCY 6 mm²). Lamps in series connection has a weakness when one of the lamps is defective then the circuit is disconnected and all lights will turn off. To avoid that happened so in every light is installed isolating transformer with primary winding comparison: secondary winding = 1:1 (see in Figure. 1)

Figure. 1. The installation of isolating transformer in runway lighting installation

In the connection of lights in series with a normal power supply, of course if there is a break in several lights, the total resistance will change which further affects the current value (according this power supply has

current constant. The change of current value is not desirable due to it will change the light intensity seen from above by the airplane pilots.

Hence, the power supply with current constant is created which is called Constant Current Regulator (CCR). With resistance then the current flowing will be constant as we expected. If we adjust the current flowing 6,6 Ampere (Maximum brightness), regardless of how many light intensity as we expected[4].

This type of CCR has a capacity of 4,5 kW (NBF 1200) and 6 kW or more (BF1200). This research was conducted in Airfield Lighting System Laboratory at,Politeknik Penerbangan Surabaya.

2. METHOD

2.1. Constant Current Regulator

2.1.1. Basic scheme of CCR

Constant Current Regulator (CCR) is a equipment that able to transform a fixed voltage power supply to be current constant power supply. The CCR works on the principle of series resonance with a certain installation (see figure 2) that can used to maintain the current load so that it is not influenced by load change.
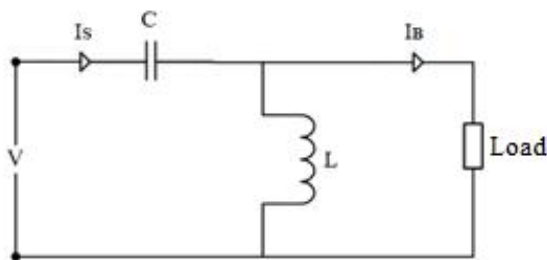
Figure. 2. Basic scheme of CCR

The basic scheme of CCR consists of L inductor and capicator C installed in series, while the load is installed in parallel with L inductor. Inductive reactance and capacitive reactance are equal, so if the load is turned off from series (R = infinity) then there is a resonance on the LC series that will draw IS current, very massive from the source[7]. Therefore, the load must be exist.
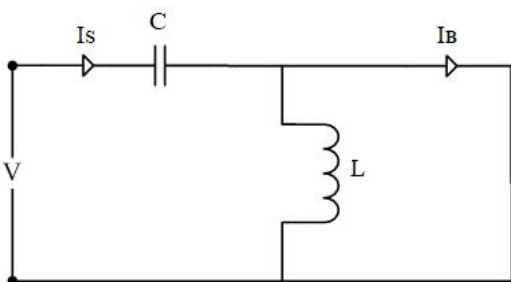
Figure. 3. A basic scheme of CCR with a load of short circuited

If the load is removed and if output of CCR is short circuited (R=0) where the whole current source of Is will directly flow to the load becoming IB (see Figure. 3). In this case, as if the whole series is only in the form of capacitor that connected to the source. Reactance capacitor is equal to –jX, so according to Ohm's law will flow a current at [7]

$$I_S = I_B = \frac{V}{-jX} = \frac{jV}{X} \quad (1)$$

where

$$j = \sqrt{(-1)}; Xc = \frac{1}{2\pi fC}; XL = 2\pi fL \quad (2)$$

2.1.2. Compensator

Whatever the load value of R will still depend on the current load I вthat remains jV/X. This current will flow in the power source that marked by a positive imaginary value (+jV/X). therefore, the compensator is added namely an inductor (Figure. 4) that absorb the current lagging or in other word, compensator is supplying the current leading.
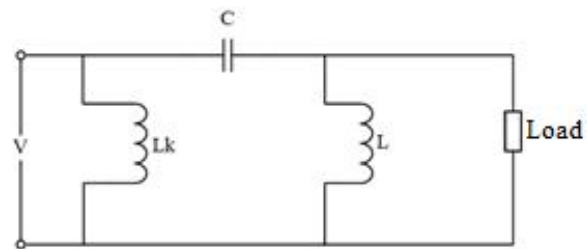
Figure. 4. Scheme of CCR with the compensator

Compensator L_K will operate the best function if its reactance is equal with reactance inductor, or $X_K = X$

2.2. Theoretical Analysis of Constant Current Regulator

By using the current loop method and Gaus Jordan method, was found the equation that conveys the relation between current and load R.
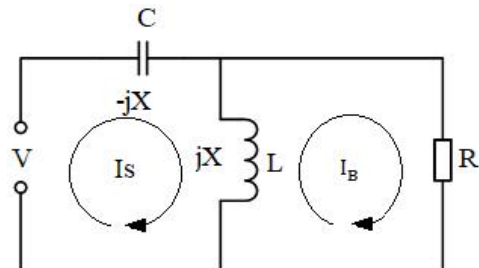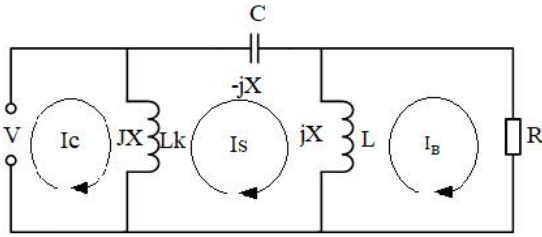
Figure. 5. Current loop on basic CCR

Figure. 6. Current loop on compensated CCR

2.2.1. Basic CCR

In Figure. 5. The following equation is obtained [3]

$$\text{Loop I}: 0.I_S - jX\,I_B = V \tag{3}$$

$$\text{Loop I}_B: -jX\,I_S + (R + jX)\,I_B = 0 \tag{4}$$

$$\begin{bmatrix} 0 & -jX \\ -jX & (R+jX) \end{bmatrix}\begin{bmatrix} I_S \\ I_B \end{bmatrix} = \begin{bmatrix} V \\ 0 \end{bmatrix} \tag{5}$$

We exchange the equation to be as follows

$$\text{Loop I}: -jX\,I_S + (R+jX)\,I_B = 0 \tag{6}$$

$$\text{Loop I}: 0.I_S - jX\,I_B = V \tag{7}$$

$$\begin{bmatrix} -jX & (R+jX) \\ 0 & -jX \end{bmatrix}\begin{bmatrix} I_S \\ I_B \end{bmatrix} = \begin{bmatrix} 0 \\ V \end{bmatrix} \tag{8}$$

$$\begin{bmatrix} 1 & (R+jX)/jX \\ 0 & -jX \end{bmatrix}\begin{bmatrix} I_S \\ I_B \end{bmatrix} = \begin{bmatrix} 0 \\ V \end{bmatrix} \tag{9}$$

$$\begin{bmatrix} -jX & (R+jX) \\ 0 & 1 \end{bmatrix}\begin{bmatrix} I_S \\ I_B \end{bmatrix} = \begin{bmatrix} 0 \\ jV/X \end{bmatrix} \tag{10}$$

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} I_S \\ I_B \end{bmatrix} = \begin{bmatrix} V(R+jX)/X^2 \\ -jV/X \end{bmatrix} \tag{11}$$

$$I_S = \frac{V(R+jX)}{X^2} = \frac{VR}{X^2} + \frac{jV}{X} \tag{12}$$

$$I_B = \frac{jV}{X} \tag{13}$$

2.2.2. Compensated CCR

In Figure. 6. The following equation is obtained [5]

$$\text{Loop I}_S: jX\,I_S - jX\,I_C - 0.I_B = V \tag{14}$$

$$\text{Loop I}_C: -jX\,I_S + jX\,I_C - jXI_B = 0 \tag{15}$$

$$\text{Loop I}_B: -0.I_S - jX\,I_C + (R+jX)I_B = 0 \tag{16}$$

$$\begin{bmatrix} jX & -jX & 0 \\ -jX & jX & -jX \\ 0 & -jX & (R+jX) \end{bmatrix}\begin{bmatrix} I_S \\ I_C \\ I_B \end{bmatrix} = \begin{bmatrix} V \\ 0 \\ 0 \end{bmatrix} \tag{17}$$

$$\begin{bmatrix} 1 & -1 & 0 \\ 0 & 0 & -jX \\ 0 & -jX & (R+jX) \end{bmatrix}\begin{bmatrix} I_S \\ I_C \\ I_B \end{bmatrix} = \begin{bmatrix} V/jX \\ V \\ 0 \end{bmatrix} \tag{18}$$

$$\begin{bmatrix} 1 & -1 & 0 \\ 0 & 0 & -jX \\ 0 & -jX/(R+jX) & 1 \end{bmatrix}\begin{bmatrix} I_S \\ I_C \\ I_B \end{bmatrix} = \begin{bmatrix} V/jX \\ V \\ 0 \end{bmatrix} \tag{19}$$

$$\begin{bmatrix} 1 & -1 & 0 \\ 0 & X^2/(R+jX) & 0 \\ 0 & -jX/(R+jX) & 1 \end{bmatrix}\begin{bmatrix} I_S \\ I_C \\ I_B \end{bmatrix} = \begin{bmatrix} V/jX \\ V \\ 0 \end{bmatrix} \tag{20}$$

$$\begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & 0 \\ 0 & -jX/(R+jX) & 1 \end{bmatrix}\begin{bmatrix} I_S \\ I_C \\ I_B \end{bmatrix} = \begin{bmatrix} V/jX \\ V(R+jX)/X^2 \\ 0 \end{bmatrix} \tag{21}$$

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} I_S \\ I_C \\ I_B \end{bmatrix} = \begin{bmatrix} VR/X^2 \\ V(R+jX)/X^2 \\ jV/X \end{bmatrix} \tag{22}$$

$$I_S = \frac{VR}{X^2} \tag{23}$$

$$I_C = \frac{V(R+jX)}{X^2} = \frac{VR}{X^2} + \frac{jV}{X} \tag{24}$$

$$I_B = \frac{jV}{X} \tag{25}$$

In implementation at the airport, L inductor was replaced by transformator step up with mutal reactance X_M, while the compensator was substituted by auto transformator with mutual reactance X_M as well. Apart from being a constant current load, CCR also function as the regulator of bright light in levels (Step by step), as required in International Civil Aviation Organization Annex 14 chapter 5 that the brightness lights must be adjustable[2]. Brightness setting can be executed by adjusting the voltage on auto transformator (see Figure.7). In this case, there 4 brightness levels, i,e., 3%, 10%, 30%, and 100%. Contactor S1, S2, S3 and S4 functioned as brightness regulator of light in levels[4].
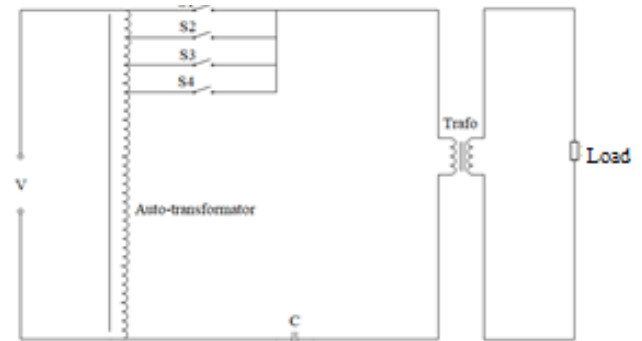

Figure. 7 CCR with multilevel bright settings

Certainly, the other safety is required to protect the contactors in order not working simultaneously (control system) which is not discussed on this paper.

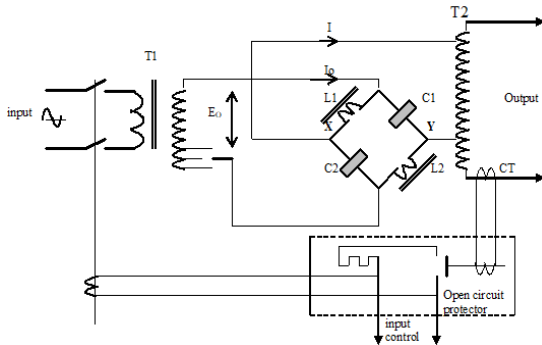## 2.2.3. Resonance Experiment Series (Learning Kit for Cadets)

Figure. 8. Static Resonance Circuit

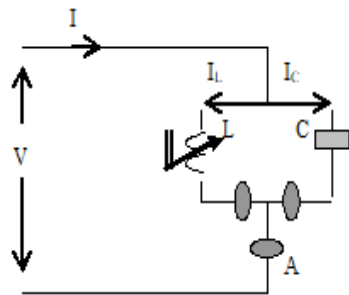**Figure. 9** Series Resonance Experiment

Information

L, C and A

lights are successive with 2 watss of power.

L is choke (5÷15 H)

C is capasitor (± 1μF)

and f = 50 hz

At resonance condition of light A is off and light L and C are on.

At resonance condition, $X_L = X_C = X_0$ [3]

$$Z_C = -j X_0 \tag{26}$$

$$Z_L = j X_0 \tag{27}$$

$$I_0 = I_C + I_L \tag{28}$$

$$I = I_L - I_C \tag{29}$$

$$E_0 = Z_C I_C + Z_L I_L \tag{30}$$

$$= -j X_0 I_C + j X_0 I_L \tag{31}$$

$$= j X_0 (I_L - I_C) \tag{32}$$

$$E = Z.I \tag{33}$$

$$= Z_L I_L - Z_C I_C \tag{34}$$

$$= j X_0 I_L + j X_0 I_C \tag{35}$$

$$= j X_0 (I_L + I_C) \tag{36}$$

Substitution equation of 5 and 4 and 6 and 3

$$E_0 = j X_0 . I \text{ and } Z.I = j X_0 . I$$

So $I = \dfrac{E_0}{j X_0} \Rightarrow$ I does not depend on the load (Z) but it depends onthe input voltage (E_0).

And $I_0 = \dfrac{E_0}{j X_{0^2}} \Rightarrow I_0$ depends on the load (Z) and It also depends on the input voltage (E_0).

From the explanation above, can be concluded that :[6]

1. Secondary current/load current is directly proportional wtih input supply voltage and be independent toward load.
2. Primary current is directly proportional with load change on the secondary side.
3. Capasitor current and voltage increase by gaining the impedance load on the secondary side.
4. Choke current and voltage also increase by rising the impedance load on the secondary side however decrease by lagging load power factor.
5. Primary power factor is directly proportional toward load power factor.

The performance curve of CCR can be seen on figure. 10 and concluded in the following :[6]

1. Input current is nearly comparable with the load.
2. Primary power factor nears the unity of 25% load until the load is full of unity power factor load.
3. The efficiency reaches 90% from 50% load to full load. The regulation of current load is 4%.
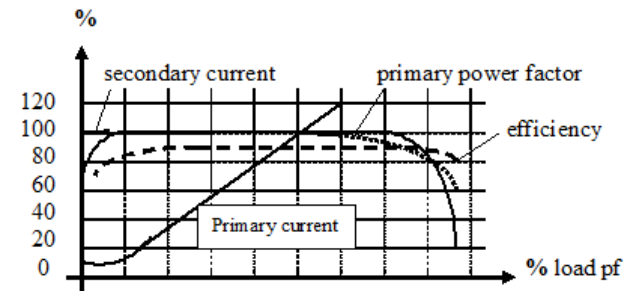

Figure. 10 Characteristic performance of static resonance

4. CONCLUSIONS

From the theoretical analysis, it has several conclusions as follows :

1. Whatever the R load value is existed, it will still flow the current load I_B amount of jV/X. Thus, this CCR has changed a constant voltage power supply to be a constant current power supply.

2. Compensator just reduces the imaginary current the source side, i.e., from VR/X² + jV/X to be VR/X² that means the compensator diminishes the current

source but does not change the current load.

3. L inductor can be replaced by transformator step up with reactance mutual XM, while compensator was substituted by auto transformator with reactance XM as well.

4. The efficiency reaches 90% from 50% load to full load.

ACKNOWLEDGMENT

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