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Harmonic Impact in Induction Generator Voltage Using Thyristor Control Reactor

Suprihardi, Yaman, Zamzami, Nelly Safitri*
Electrical Engineering Department, Politeknik Negeri Lhokseumawe, Indonesia
*Corresponding author, e-mail: nellysafitri@pnl.ac.id

Abstract

As commonly known that theload fluctuations that have been performed on an induction motor operated as an induction generator (IG) triggers unstable induced voltage and frequency. Asthe result, the load that receiving the power quality is not running properly and the efficiency is low. The problems that have beenmitigated in this research in such way is the stability of the voltage that generated by IG due to fluctuating loading, and the harmonics can be damped by single tuned due to the work of thyristors and non-linear loads. The used method is the Ziegler-Nichols method by measuring and testing the design of prototype to get the best performance in stabilizing the voltage by using thyristor control reactor (TCR). The results showed that the induced generator with single tuned filter and TCR to nonlinear load variation at 1618 RPM is maintained stably for the voltage and frequency. Although, 3rd order harmonics of voltage and current that has been tuned can be dampedby using THDI 8.36%. Furthermore, it can be said that the response that generated by voltage control system using proportionalintegral (PI) control in 1kW-4 poles three-phase IG with additional and reductionalload generated a stable response.

Keywords*: Load fluctuations, Induction generator, ziegler-nichols, TCR, voltage control system*

1. Introduction

Induction motors are currently and widely used as generators and applied to alternative generating systems or new renewable energy sources. An induction motor can act as a generator when rotated beyond its synchronous spin and the reactive is powered at its terminal in the form of a capacitor. The larger the capacitor is provided, the greater the voltage that generated by the induction generator (IG). The greater the load that provided to the IG, the greater the voltage dropped [1]. The simply excess that used to the induction motor as a generator is not complicated, and cheap and the size of the form and capacity is very much in the market. The turbine that rotates the generator does not require to be at its sync speed [2]-[3].

The weakness of the IG is whenever the loading takes place it resultsin a great voltage drop if it is applied to the inductive load. The capacitive and inductive loadings are impedances that have current flow in opposite direction. From this basic principle, the development the regulation of reactive power on the induced generator by regulating the current on the capacitor or current setting on the inductor [4] can be done. Several studies hav been done on regulatingthe reactive power of IG that has been developed in the application using flexible AC system (FACTS) with various models such as Static Var Compensator (SVC), STATCOM, tapchanging of the transformers, Line drop compensation, series capacitors, and SSSC [5]-[8].

The reactive power management model with Thyristor Controlled Reactor (TCR) which is part of the SVC group has been simulated in Matlab provided good results [9]-[11]. However, the switching system of the active components of the thyristor in regulating the reactor current contributes rise to a high odd harmonic sequence on the electrical system [12]. Unstable voltages and high harmonics indicate poor power quality and lead to overheating of the plant and affect the performance of other apparatus using that voltage. From the previous research, the average reactive power setting using a fix capacitor-thyristor controlled reactor (FC-TCR) system, which is part of FACTS technology used as a voltage stabilizer by regulating the reactive power [13]-[14]. Research relating to the regulation of reactive power and simultaneously as a harmonic damper due to the switching system and nonlinear load has not

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been made especially applicable to the induction generator. Such a generator model can be developed in Indonesia since the energy source is very remote.

In this research, the authors test the reactive power regulation system using TCR and single tuned filter system by utilizing static capacitor which is coupled with inductor L. The problem to be studied in this research is adjusting the voltage generated by induction generator is stable or constant due to fluctuating loading. Then the harmonics can be damped by single tuned due to the work of thyristors and non-linear loads. The author also analyzes the ability that can be done by TCR and fixed capacitors are added inductor L in series.

The proposed method is by testing the i.e., a constant static capacitor that is supplied to the induction generator, which has been added an inductor L in series. Then TCR serves as a regulation of the reactive power requirement of the IG The initial step performs the calculation in determining the value of the capacitor as a reactive power distributor and the inductor value of L as well as the filter. The second step calculates the reactor value as a reactive power absorber to stabilize the voltage. The third step is to test the prototype in regulating reactive power with proposal integral (PI) control.

2. Research Method

The research activities offered are divided into three stages, namely, assembling a single tuned prototype to reduce harmonics and TCR controlled by the PI controller by adjusting the angle of ignition automatically in stabilizing the voltage [15]-[16]. The prototype is tested on a three-phase 1kW three-phase induction motor, 380V, 50Hz, 80% efficiency and power factor of 0.76 lagging as illustrated in Figure 1.

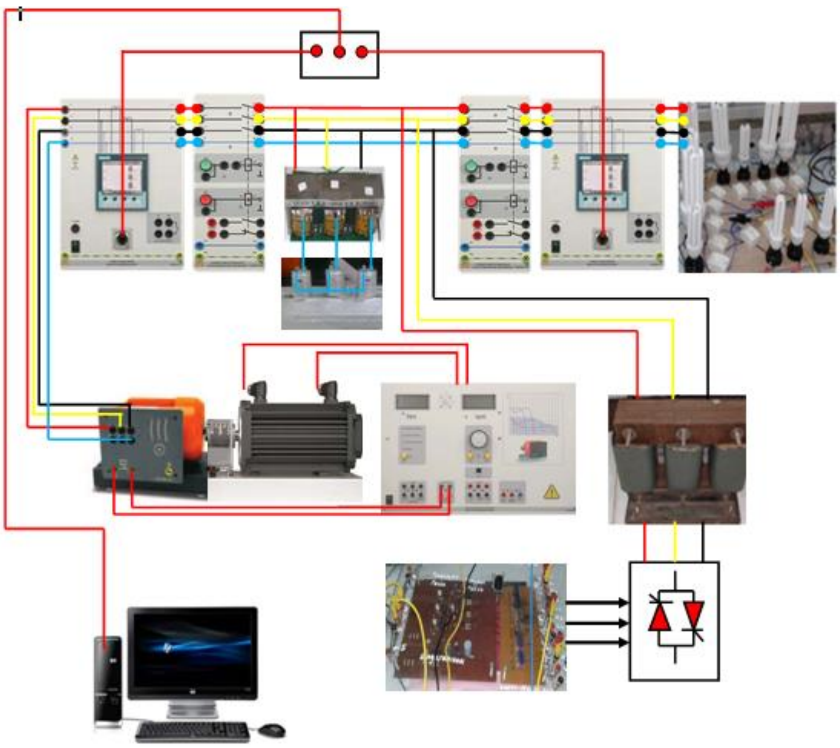

Figure 1. TCR and single tuned prototype testing sequences

The observations were made by measuring the single tuned prototype and TCR to obtain the steady voltage and the highest muted harmonic order. The next observation is the voltage response that occurs by TCR PI-controlled to the load changes.Calculations are made to the capacitor requirements as a reactive power generator of IG. The calculations are performed based on the nameplate of the induction motor that has been mentioned earlier. The value of the multiplier k is obtained at 1.47, thus the reactive power requirement (Q) [6] [16].

$$Q_g = k \ x \ Q_m \quad (1)$$

$$C = \frac{Q_g}{2.\pi.f.V_p{}^2} \quad (2)$$

The result of calculation of reactive power requirement is 1571.5917 VAR with capacitor value per phase equal to 35 uF. Calculation of Inductor L value of condition of reactive power provider C is connected in series, so C used as reactive power provider has changed function as a single tuned filter. The value of the filter inductor can be calculated based on the value of the capacitive reactance X_c in the order of the greatest n^{th} harmonic is as follow,

$$XL = \frac{Xc}{n^2} \quad (3)$$

$$L = \frac{Xl}{2\pi.f} \quad (4)$$

The calculation results of Inductor L value needs to be connected series with capacitor C equal to L=33 mH at 3rd harmonic order reactor at TCR used as reactive power regulator [17-20]. The controllable reactance of the TCR part, which is the parameter of resistance R=35 ohms and inductance L=6 Henry. The circuit of the reactor flow controller uses an open loop system in regulating the reactive power consumption of load changes such as Figure 2.

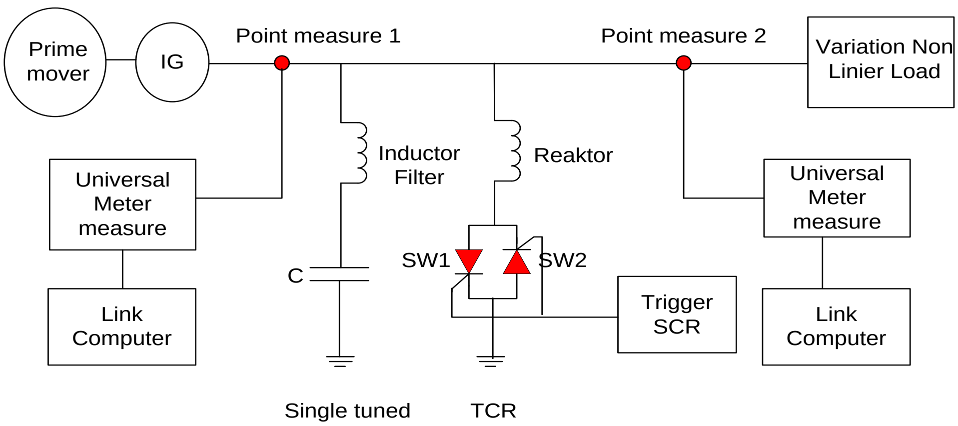

Figure 2. Single tuned filter and TCR filter circuit

Observation is done by taking measurement data as follow,

a. Inductor measurement and Reactor with RLC meter
b. Measurement of voltage and power factor of induction generator with capacitor to load change
c. Voltage and power factor measurements of induction generators with single tuned to load changes
d. Measurement of voltage, power factor and THD induction generator with fixed capacitor and TCR trigger angle to load changes
e. Measurement of voltage, power factor and THD induction generator with single tuned and TCR trigger angle to load changes

The circuit of the reactor current controller uses a closed-loop control system in regulating the reactive power consumption of load changes such as Figure 3. Firing angles range from 90˚ to 180˚, the modes of operation of TCR varies from inductive to capacitive modes as the firing angles increase [11].

Observation is done by taking measurement data as follow:

a. Measurement of the voltage sensor for setting the working range of the sensor
b. Determination of PI parameters by tuning the R-L circuit using the Ziegler-Nichols method.
c. Recording generator induced voltage response with single tuned to load changed with PI control on TCR.

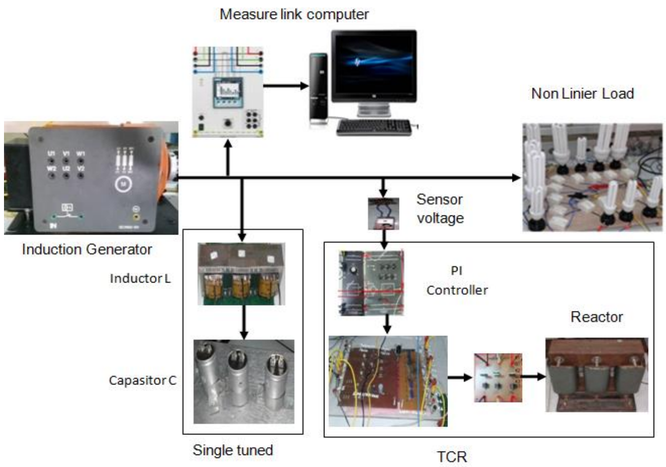

Figure 3. TCR prototype testing circuit with PI control and single tuned

3. Results and Analysis

The test results of IG power generator of 1kW, three-phase, 4 poles, 380V, 50Hz, 80% efficiency and 0.76 lagging power factor, and static capacitor calculation C=35 uF, inductor filter L=33 mH, reactor TCR with resistance R=35 Ohm and inductance L=6 Henry.

3.1. Voltage, frequency and harmonics measurements

Measurement of voltage and frequency of load conditions increased without TCR obtained data as in Table 1. This test is performed to determine the voltage and frequency due to changes in load.

Table 1. Measurements of voltage and frequency of load conditions increased

Load (Watt)	Torque (N-m)	voltage (Volt)	Frequency (Hz)	THD_I (%)	Cos Φ IG	Cos Φ Load
0 W	1,87	220	50	4,4	0.01	-
135 W	2,76	212	49	6,1	0,08	0,69
270 W	3,69	202	48.6	10,4	0,17	0,76
417 W	3,89	196	48	12,4	0, 21	0,78

Table 1 can be explained as an IG with static compensation 35 uF at 1528 rpm shows the voltage and frequency decreased as the load increased. The load and frequency measurements of load conditions increase with TCR and single tuned data can be seen in Table 2.

Table 2. IG with single tuned filter and TCR to nonlinear load variation at 1618 rpm

Load (Watt)	Reaktor TCR (Henry)	Torque (N-m)	Voltage (Volt)	Frequency (Hz)	THD_I (%)	CosΦ IG	CosΦ Load
0	0,6	1.87	220	50	5.5	0.01	-
135	1,2	3.65	220	50	9	0.25	0.55
270	6	4.56	220	50	8.36	0.19	0.6

Table 2 can be explained as increasing the load by using a reactor and a single tuned then it shows the voltage and frequency generated are fixed. Frequency can be fixed if the torque setting of the prime mover is regulated. If not, then the frequency must be carried out its own control.The measurement of THD in the harmonic graph of voltage and current condition before the filter process can be seen in Figure 4.

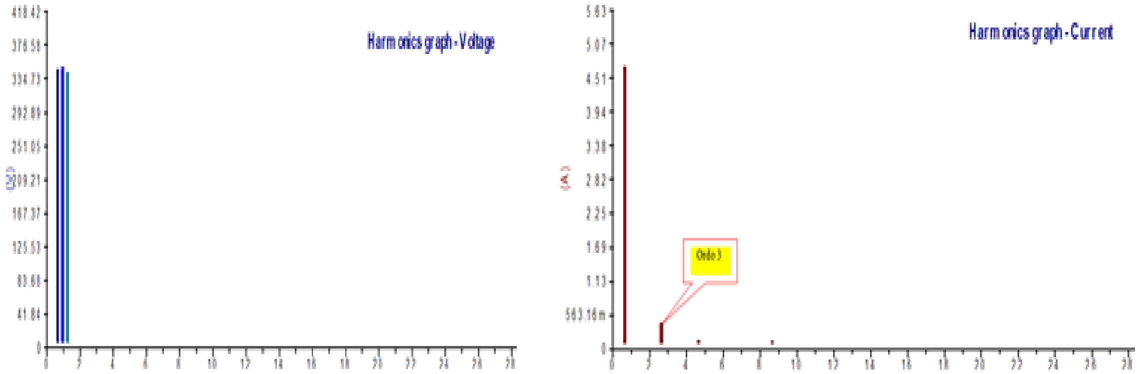

Figure 4. THD_V and THD_I spectrum of order 3 before filtered

Figure 4 can be explained that the harmonic graph of order 3 is the highest harmonic of the other order with THDI of 10.4%. This is because that the harmonic filter has not been done single tuned tuning order 3. Measurement of THD in harmonic graph voltage and current condition after the filter can be seen in Figure 5. It explained that the order 3rd harmonic has been darkened and no longer seen in the current spectrum with THDI of 8.36%.

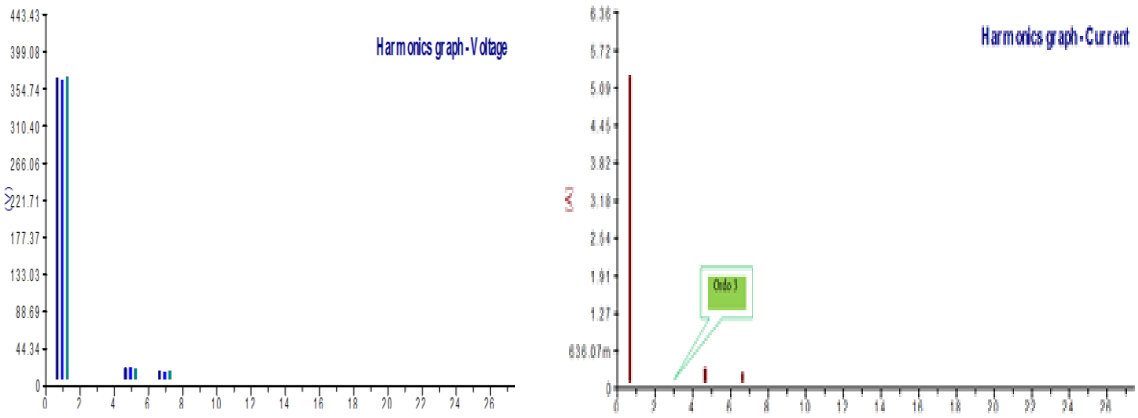

Figure 5. THD_V and THD_I spectrum of order 3 after filtering

3.2. TCR Settings with PI Control

PI control parameters obtained by tuning based on Ziegler-Nichols method. In PI controller, the gain values are adjusted to get optimum performance. These gain values can be tuned based upon Ziegler Nichol's tuning [21]. The proper PI control parameters on the voltage control system affect the accuracy and speed of the response. PI control parameters after yellowing are: Kp=6 and Ti=0.99 seconds.Testing of the voltage control response to the Induction generator plant IG with a closed loop system when the load is adding. Voltage control of IG response during load addition is Illustratedin Figure 6.

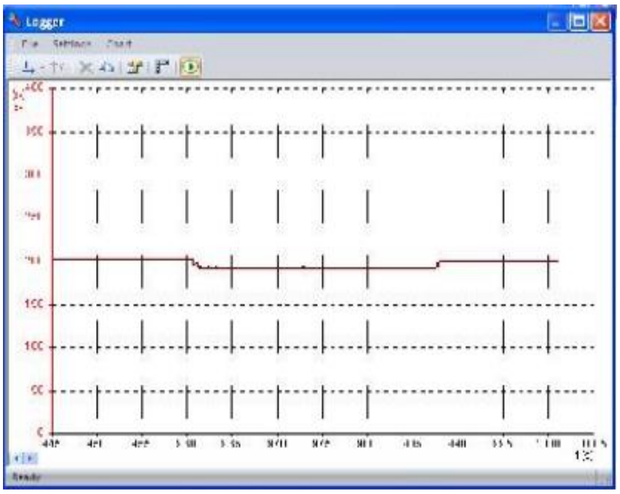

Figure 6. Response to voltage when adding load

Figure 6 can be explained as the normal load 300W with a voltage of 200V, frequency 50Hz, then made the additional of 180W of the load. Voltage response at 180W increases, the decreased voltage reaches 193V with a fixed frequency of 50Hz. After 25 seconds, the voltage returns to normal at 200V with a frequency of 50Hz.Testing of the voltage control response to the IG with a closed loop system during load reduction. The voltage control of IG response during load reduction can be seen in Figure 7.

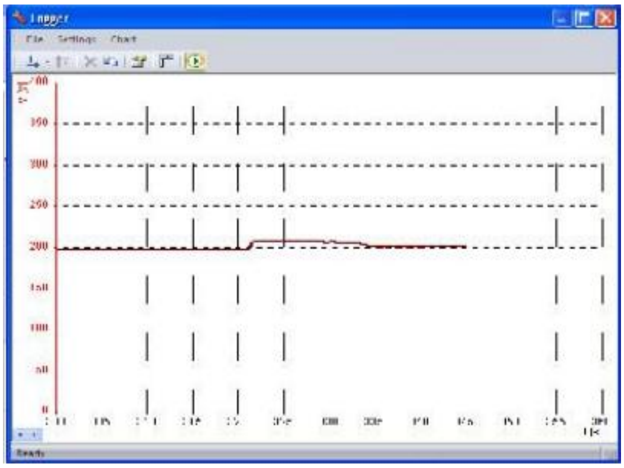

Figure 7. Voltage response during load reduction

Figure 7 can be explained that Normal load 375W with a voltage of 200V, frequency 50Hz, then do a 75-Watt reductional load. The load reduction response is 75W, the rising voltage reaches 215V with a fixed frequency of 50Hz. After 12 seconds, the voltage returns to normal at 200V with a frequency of 50Hz.

4. Conclusion

Measurements and prototype testing performed in this research can be concluded: Induction generator with single tuned filter and TCR to nonlinear load variation at 1618 RPM result in stable voltage and frequency, 3rd order harmonics of voltage and current tuning can be muffled with THDI 8.36%, and Response generated by proportional PI control on a three-phase IG 1kW 4 poles with load addition and load reduction produce a stable response.

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