Automatic Capacitor Switching for Self Excited Induction Generator Using Non-Linear Regression for Wind Power Application

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***Abstract* - Generators for wind power plants has much importance to obtain long life and durability because of the hard environmental conditions. Especially, overseas application has extreme conditions such as wide range temperatures and humidity. In order to obtain high durability, low maintenance or no maintenance generators may have good option to install long life wind power plant. Asynchronous generator has no maintenance and only three capacitors are adequate to produce energy. On the contrary voltage regulation is not easy. Three parameters, revaluation per minute, connected capacitors and load characteristic affect the voltage regulation. Especially in order to obtain constant frequency and regulated voltage is not easy. Only one parameter is capacitor to regulate the voltage. In this study, an offline application targeted and voltage regulation is addressed for inconstant load. This study offer a mathematical approach to prediction capacitor value using non-linear regression based on experimental results.**

***Keywords* - Wind power, Asynchronous generator, Non-linear Regression, Capacitor switching.**

I. Introduction

Wind power is a renewable energy power that it has increasing popularity in application. Unlike sun based power plants, wind power has extreme conditions to produce energy [1-2]. Especially overseas application has extreme conditions such as wide temperature alteration and wind force [3-4]. Maintenance is one of the biggest problems of the wind power application. Asynchronous generator is same structure with induction motor structure and has a squirrel cage as it. Thus Asynchronous generator has no maintenance through the life. Moreover Asynchronous generator has no excitation input to regulate the power [5-7]. Revaluation per minute (RPM) and capacitor are simple way to obtain voltage regulation for inconstant load. In this study, an offline generator application is designed to obtain experimental results. In order to regulate the generated voltage is used capacitors group related load. Generally capacitors are switched by dry contact structure regarding capacitor current and voltage [8-9]. Capacitors values are divided according to binary counting method to obtain maximum resolution. Thus maximum voltage regulation quality may obtain. Regulation by capacitors is not expensive and cost effective method to obtain adequate regulation. Following section is devoted to material method and experimental results to evaluate.

II. Materials And Method

Asynchronous generator is robust generator to produce wind power energy. Moreover asynchronous generator has no maintenance compared to other generator models and its maintenance time related to ball-bearing and roller quality. On the contrary, Asynchronous generator has no excitation voltage input to regulate the output voltage. Output voltage is can be obtained easily just connecting a capacitor at adequate rpm. Obtained voltage regulation depends on load and rpm constant characteristics. An experimental system was installed to test asynchronous generator for different loads. Obtained capacitor and RPM were noted to evaluate and create a regression. Fig. 1 shows a SEIG application for offline application.

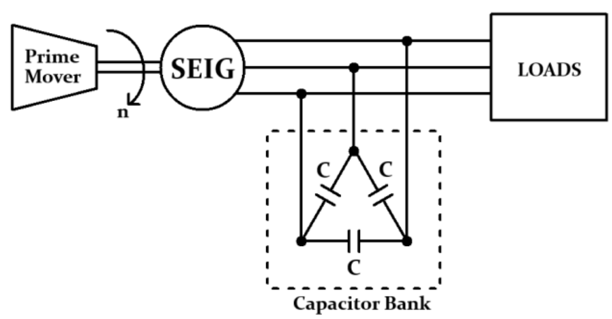

Figure 1: SEIG connection for offline in a wind power application

Capacitor is one of the most important parameter to obtain voltage regulation because of its cost effective and easy solution. Capacitor must be chosen regarding current and voltage consideration to install robust structure. In order to obtain maximum resolution, generally capacitors divided in groups regarding binary counting system [10-11].

Load characteristic is determined by adjustable resistive load. In order to obtain different loads three pieces 15 Watts (W) and three pieces 28W bulbs used. Total load can be arranged to 120W.

In order to regulate the output voltage, 0.22uF, 0.47uF, 1uF, 2uF and 4uF capacitors are used. Maximum capacitor is handled as 3.69uF to regulate output voltage. Fig. 2 shows motor, generator and coupling.

Figure 2: SEIG and PMSM motor is coupled to each others

Experimental system includes measuring circuits to obtain voltage and current. Capacitors are connected each others as delta connection and Load is connected as star. Fig. 3 shows experiment setup, capacitors, loads and etc.

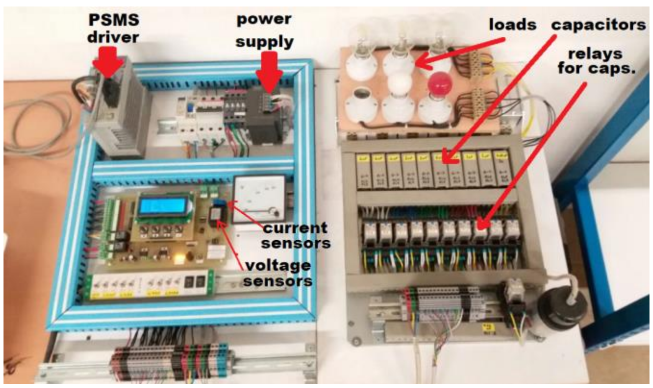

Figure 3: Used experimental setup for testing of SEIG

PMSM driver can be controlled by manually and computer to obtain high resolution rpm. Especially PMSM was chosen as higher than SEIG to reduce rpm collapsing by load characteristics. This is lead to obtain high accuracy for target equation. PMSM motor simulates wind power, SEIG generates energy and capacitor regulates to generated voltages related to load characteristics.

PMSM motor is 3000 RPM and 750W. Number of capacitors is 10.

SEIG is 250W and 1390 RPM induction motor. In order to simulate the wind flow power, computer controlled synchronous motor (750W) and synchronous motor driver unit were used. Basic connection of experiment setup block diagram was shown Fig. 4.

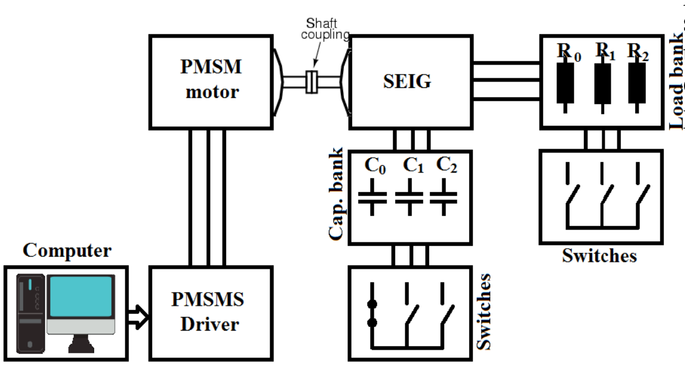

Figure 4: Block diagram of proposed system

In order to test the system, wind power simulated by computer controlled PMSM driver and PMSM motor. PSMS motor is 300W and has higher RPM than the SEIG to test over RPM behavior of SEIG output. C_0 capacitor was arranged as start-up capacitors obtain firs starting. There is no need to switch start-up capacitor. The rest ones includes on it to increase the capacitor value.

Computer can control the PMSM motor from zero to 1500 RPM with 0.1 Hz resolution. We aim to obtain constant speed to obtain certain capacitor value to regulate the output voltage.

Capacitors are connected as delta connection among the SEIG windings as Fig. 5. Computer collects the current and voltage values as real time from the experimental system to storage. Analogue digital converter has 12 bit resolution and evaluates the current 0.1Ampere resolution.

Collected current and voltage values are used to evaluate in non-linear regression to obtain capacitor characteristics.

Non-linear regression is a way to find out a solution between inputs and output [12-14]. A non-linear model is based on least squared method (LSM) to find solution between capacitor value and inputs. LSM is widely used to find a solution between input and output. Moreover system is not be linear and gives fast solution [15-17].

$$y = a + bx_1 + cx_2 + dx_3 \tag{1}$$

LSM finds a polynomial approaching between capacitor value and inputs. Here is solution is not linear to reduce prediction error.

$$\begin{pmatrix} \sum_{n=1}^{N} f(x_n)^2 & \sum_{n=1}^{N} f(x_n)g(x_n) \\ \sum_{n=1}^{N} f(x_n)g(x_n) & \sum_{n=1}^{N} g(x_n)^2 \end{pmatrix} \begin{pmatrix} a \\ b \end{pmatrix} = \begin{pmatrix} \sum_{n=1}^{N} f(x_n)y_n \\ \sum_{n=1}^{N} g(x_n)y_n \end{pmatrix} \tag{2}$$

LSM is a method to find a solution between inputs and outputs regarding minimum total error.

III. Test And Results

Proposed off line SEIG application was designed and tested with 250W SEIG. A higher motor is coupled to SEIG to simulate the wind. PMSM motor especially was chosen higher power than the SEIG to evaluate SEIG characteristic at over speed wind power. Fig. 5 shows Computer connection of ADC to obtain current and voltage values. In this study, current was obtained from 0 to 2A and voltage was obtained 0 to 440Volts phase to phase.

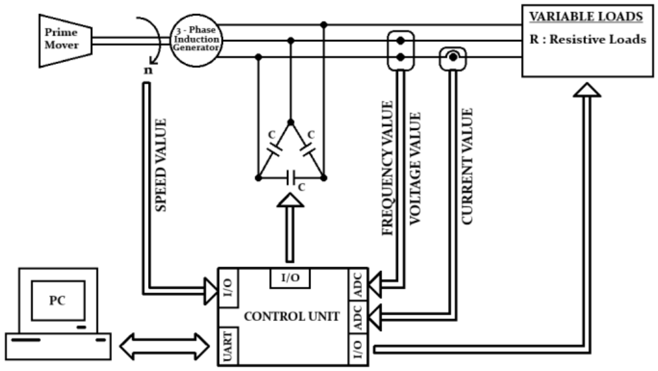

Figure 5: Designed electronics card to read generator current and voltage

Wind power simulates by PMSM motor. PMSM motor is driven by PMSM driver and speed of PMSM motor is changeable manually. As first, SEIG generator was excited by PMSM motor at determined speed to find out. Fig. 6 shows created graphic using experimental real application data.

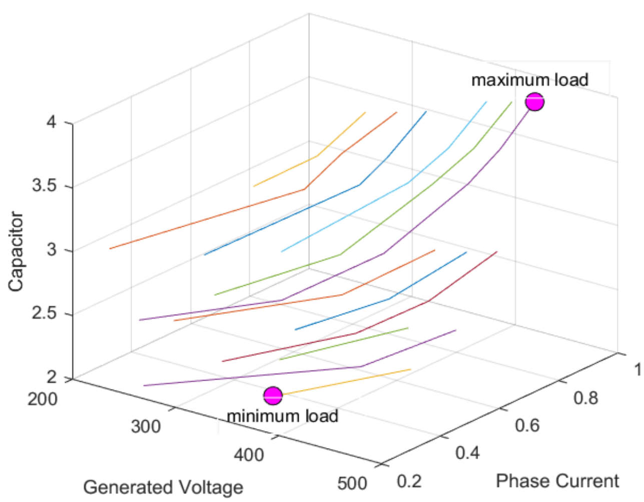

Figure 6: Relationship among load, and inputs (current, voltage and capacitor)

According to experimental results, curve fitting software is used to calculate and to obtain a function to describe the targeted capacitor related to load capacity. Curve fitting software uses the least squared model to obtain the function and shown Equ. 3

$$y = 9.22508 - 0.005452\, x_1 + 0.005489\, x_2 + 0.003758\, x_3 \qquad (3)$$

Where, x_1 is rpm, x_2 is generated voltage by generator and x_3 is current.

y curve shows capacitor value. Electronics control unit related to current instant capacitor values and combined one or more capacitor each other to obtain target capacitor. Capacitor are sequenced 1x, 2x, 4x and etc as inspired from binary counting system.

Table 1 shows used and calculated capacitor values for same target voltage. In the application, 6 capacitors are combined as 2, 0.47, 0.22, 3uF.

Table 1: Capacitors Values.

Capacitor Values			
	Max	**Average**	***Min***
Experimented	4uF	3uF	*2uF*
Calculated	3.91uF	2.71uF	*1.51uF*

From Table 1, calculated capacitor by Equ.4 is close to real experimented value. Table 2 shows maximum and minimum error point's situation in real applications. For example maximum error is obtained at 1500 RPM and there is no load during the max error. On the contrary, minimum error is obtained at 1400 RPM with 45W load characteristic.

Table 2: Capacitor Errors Situations.

Capacitor Error Situations					
	Speed	**Current**	**Voltage**	**Load**	***Max***
Max. Err	@1500	@0.88	@454	@0	*0.46*
Min. Err.	@1400	@0.58	@352	@45	*0*
Average					*-0.29*

From the Table 3, maximum error value situation is measured at no load running at 1500 RPM with 4uF capacitor using Equ.4. Voltage can be calculated as reverse for calculated capacitor.

Table 3: Voltage regulation at max, min and average error points.

Line Regulation (%)			
	Target voltage	**Obtain. Voltage**	***%***
No load	454	537	*15.4*
45W	352	352	*0*
84W	424	480.37	*11.73*

From the Table 2, maximum error value situation is measured at no load running at 1500. Capacitor could be calculated using Equ.3 according to load characteristics instantly.

Function is obtained using Curve Expert 1.3 which is free on its own website and downloadable [18]. Curve Expert finds curves between inputs values and output.

IV. Evaluation Of The Results

In this study, a SEIG application was applied and obtained real values related to load and SEIG characteristics. Although a SEIG application looks easier. It is not easy to obtain good line regulation related to redundant parameters redundancy. In this study, in order to control the line regulation real voltage current and speed are used and using these three parameters Equ.3 was created via curve expert 1.3. Obtained curve based on least squared method to find best approximation between inputs and outputs. Curve expert calculated the Equ.3 with 0.92% success evaluated with R^2 as 0.915248. R2 is a way to measure of the success in literature and shows similarities of two variables [19-20]. During real application after experimental testing, average line regulation success obtained lower than 11.7%.

V. CONCLUSION

In this study, induction motor was used as generator to reduce maintenance and run under hard conditions such as cold weather conditions. This kind of application just needs capacitors to run and control the generated voltage. Because of this simplicity, induction generator has importance advance in hard running condition especially north countries which have strong winter seasons. This study uses capacitors groups to switch related to load characteristics to obtain line voltage regulation. Although SEIG characteristics depend on more than one parameter, load current, capacitors, speed, studied approximated function finds optimum line regulation with measuring only current, speed and voltage as closed system. The obtained function can be reached the experimental real results lower than 11.3%. Moreover, success can be improved by increasing the binary combination length of capacitor. In addition the small error percentage, through the load increasing regulation characteristic gets better than no load running. These results encourage us to use SEIG in wind power generation.

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