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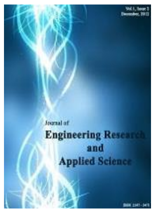

Variac controlled reactive power compensation

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Abstract
The importance of reactive power compensation has increased for efficient use of electric energy. Nowadays, central compensation that increasing number of steps is widely used. But, installation and maintenance costs cause compelling effects. In this study, Reactive energy to be supplied to the grid was attempted to be kept at the desired value by adjusting the voltage applied to the capacitor. For this purpose, variac that is adjustable output voltage with the help of a spindle was used. This variac is single-winding transformer. Different currents were obtained from a capacitor by adjusting the output voltage thanks to variac that is connected to the servo motor. In the study, three capacitors are connected to separate phases. Inductive loads are considered. Loads that are connected with the help of switch were read as input thanks to relays in the Arduino circuit. Servo motors was rotated at desired angle through the Arduino software that is loaded into memory, so power factor was adjusted to the desired value. Thus, different values reactive currents were provided from a capacitor. The results show that variac controlled compensation has a more effective performance than multi-steps central compensation.

Keywords: Compensation; energy quality; capacitor; variac

1. Introduction

With the demand for electric energy increasing day by day, production should be increased as well; but it is not simply enough. It is very important to use this energy in an effective and productive way. Most of the electrical receivers pull reactive power from the network beside active power [1]. In order to increase efficiency, reactive power control is done in transmission lines [2-3]. It is possible to decrease losses by using energy sources more effectively via reactive power control [4]. Nowadays, reactive power control relay and capacitor connected to loads are taken and removed into the circuit according to demand.[5] The capacitive reactive energy that is necessary for loads in the system can be supplied by the capacitor statically[6]. Thanks to this system, the reactive energy pulled by inductive loads is decreased [7-8]. However, when the load is big and high-speed, necessary reactive energy cannot be fulfilled by traditional method [9]. Current status of central compensation is SVC [10-11]. In SVC systems, capacitors can be received and ejected by rapid switching via thyristors. Besides rapid switching, reactive energy in different rates can be obtained from reactors in a controlled way [12-13-14]. In a power parameter edited plant, when a capacitor at any stage steps into circuit, it gives maximum rate of reactive energy. In fact, the necessary energy can be fulfilled even half of the capacitor. The surplus reactive energy causes to occupy the line. Composing plus stages is a current method in order to fulfill different demands. It is an indispensable reality that configuration and care costs will increase. For this reason, all factors must be taken into consideration while doing compensation [12-13-14]. The necessary energy can be fulfilled from one or more capacitor instead of forming many stages. By adjusting the voltage adapted to capacitor, reactive energy can be hold on intended value. Variacs is a kind of transformer, of which output voltage can be adjusted via a shaft on. In this study, different currents are obtained from capacitor by adjusting output voltage via a servo motor connected to variac shaft. In the study, three capacitors are connected to different phases. Loads are taken into circuit with switch and with the aid of relays, which load inserted is read on Arduino. Increasing reactive power parameter is enabled by rotating servo motors intended angle with the aid of software loaded on

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Arduino memory. Reactive power and stream is reduced. Both location and speed control of servo motor can be done.

2. Materials and Methods

The design of the study, compensation practices in todays have been considered. In the experimental circuit, unlike the present applications a variac (autotransformer) has been used instead of contactors. A variac which provides a different voltage on its output differing from its input is a single winding transformer. When the shaft on variac is rotated, the number of turns, thus, output voltage is changed because the carbon brushes touch to different points. In order to rotate the variac, a servo motor is used. Also, in order to rotate the shaft to desired angle, an Arduino microprocessor has been used. Software is written and loaded to Arduino for the purpose to control of three servomotors.

2.1.Condensers

A condenser is capacitor that used in power factor correction. There are several compensation capacitors having different power and voltage value on the market. There are two type capacitors including boxed and cylindrical that used in compensation applications. Cylindrical capacitor is more preferred because of less risk of explosion.

Condensers generally that are produced on the network voltage of working voltage, produced in various values such as 230-240-440-525-600 Volt. In this study, capacitors with one phase are used which 0, 5 - 1 - 2 kV power.

2.2.Condenser Calculation

When voltage is applied to the capacitor, it is loaded a charge due to a load capacity. The capacity value of a charged condenser; Capacity of condenser is determined by the production as can be seen the capacity of a capacitor Equation 1 and it is constant.

Where C: capacity values between two level plates (Farad) ε,
Dielectric constant (0.0085)
F: Electrode levels (m^2)
d: is distance between the electrodes (m).

$$C = \varepsilon \frac{F}{d} \quad (1)$$

2.3.Capacitive Reactance

Capacitive reactance is the resistance which shown in the condenser against to current in the alternative current. Capacitive reactance depends on the frequency as shown in equation 2. Mains frequency is fixed at 50Hz. Therefore XC is fixed.

$$X_c = \frac{1}{2\pi f C} \quad (2)$$

2.4.Current Calculation

$$I_c = \frac{U}{X_c} \quad (3)$$

Current and voltage are directly proportional as shown in Equation 3. Because HC and Xc is fixed as shown in equation 1 and equation 2.

Ic: Capacitors Current (Amperes)
U: Capacitor Voltage (Volt)
XC: Capacitive reactance (Ω).

In this study, currents of different values of a capacitor obtained changing the voltage

2.5.Power Calculation of Condenser

$$Q_C = P\,(\tan\varphi 1 - \tan\varphi 2) \quad (4)$$

Tangent value obtained from the power factor in the initial state of the system

$\tan\varphi 1$: Tangent value obtained from the power factor in the initial state of the system

$\tan\varphi 2$: Tangent of the required power factor value

Q_C: Capacitor power value is necessary for compensation

Various methods can be used in capacitor power calculation. Equation 4 is generally used method. According to the value found by calculating, the number of steps performed and it is ranked according to values greater than minimum. In some cases, a condenser which is not used connected in order to fill the number of stage. It increases the cost and board size, and complicates the cooling process. The result of our work, the number of stage is decreased and unnecessary use of condenser is inhibited.

2.6.Variacs

Variac is called in other words, auto-transformers. Structure, single-layer winding and a movable shaft are difference from other transformers. Windings are wound on the toroidal core. They allow us (1) the alternating voltage applied to the input to lake on different values from output. Insulation of the windings are etched until the brush part. Carbon brushes acting on windings can be manual or motor control.

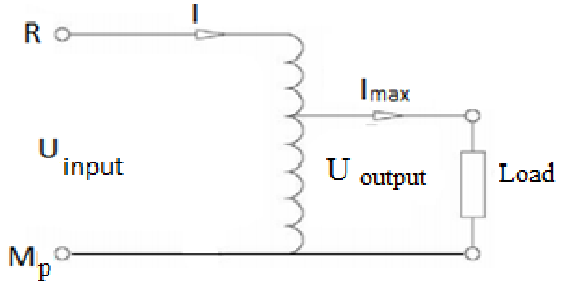

Figure 1. Variac input and output voltage display.

In the study variac shaft is controlled by servo motor. Variacs installed servo motor are given in the attached figure 2. Used Variacs input voltage is 220 V AC, their output voltage is in between 0-220 volts AC. One of the input and output terminals are common pin. Two limit switches are used to limit the rotation of the shaft. The result of motion of the variac shaft results was obtained the desired capacitor voltage and current. The variac brush pressurizes wraps about 3-5 N/cm^2. If pressure is too much, bandages are worn; if less can occur arc [15]. Therefore carbon brushes must press the winding at a normal level. Shaft acting on the winding has adjusted the tension by changing the number of windings.


Figure 2. In this study Variac attached servo motors used

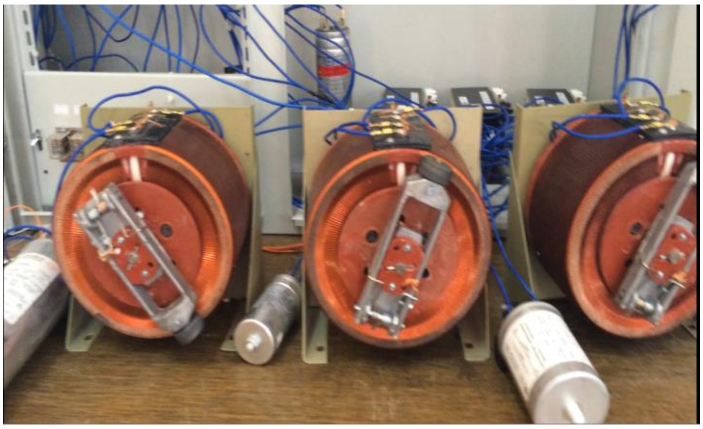
Figure 3. In this study Variac attached servo motors used.

2.7.Servo Motors

Servo motors are motors which are returned until the desired angle with the aid of a particular signal and have closed loop control [16]. In this engine speed, position, torque and hybrid can be controlled. To adjust the PWM pulse width and to make speed control are possible [17-18]. There are servo controlled motor that can work with both AC and DC voltage. In study working with the DC+5 volt servo motors can be rotated 180^o 210^o and 360^o servo motors are used. It is made with the help of pieces which are prepared variac shaft connection with drive wheel.

2.8.Arduino

Servo motor signal input and output pins	1
Atmega 328 Microprocessor	2
+5 Volt circuit power supply input	3

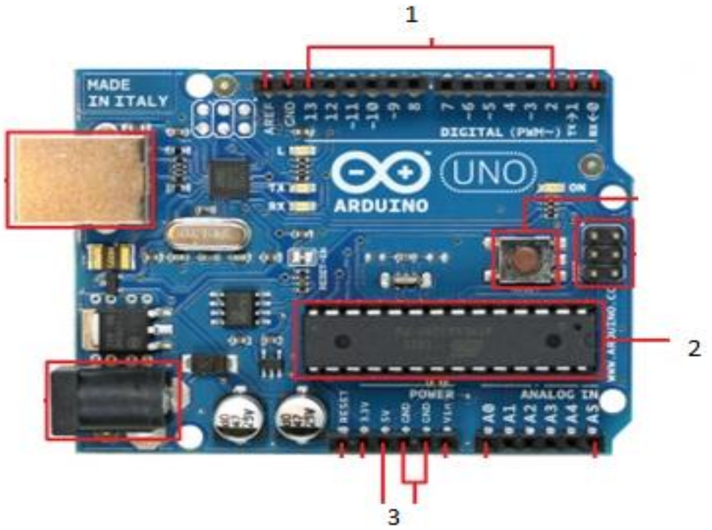

Figure 4. Arduino Uno ports.

3.The circuit diagram and studies of the experiment

Unlike other applications in the study Variac was used instead of contacts. Variac output terminals are connected to the three capacitors. No matter what phase power factor falls as it rotated to which the phase angle required servo motors and factor is raised. The necessary angle was obtained by the test results. What phase needed for a capacitor was determined with a relay.

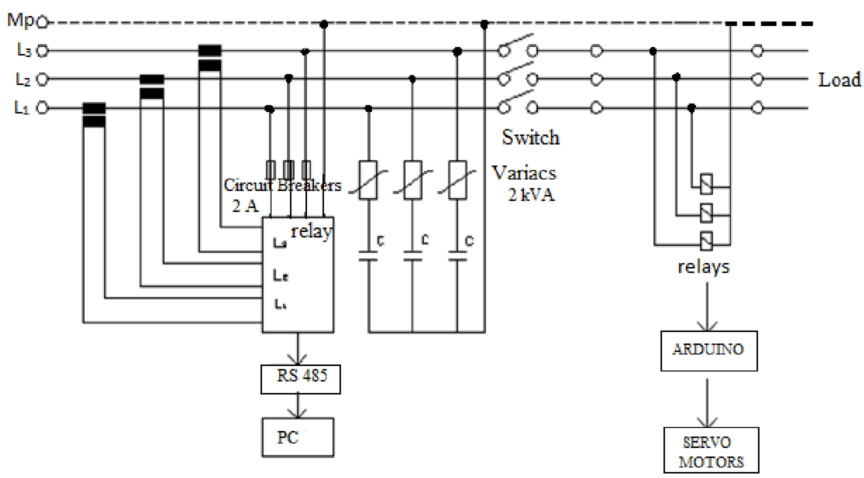

Figure 5. Schematic diagram of the experiment.

The circuit diagram of the study is given in Figure 5. The used current transformer conversion rate 50/5, the relay coil connected to the load side voltage is 220 volt current ampere rating of 5-10.The algorithm flow chart of the prepared software is shown in figure 6. In the Arduino, three pins are used as digital input and three pins are used as servo motors signal outputs. The loops of three servo motors are provided in common in the flow diagram.

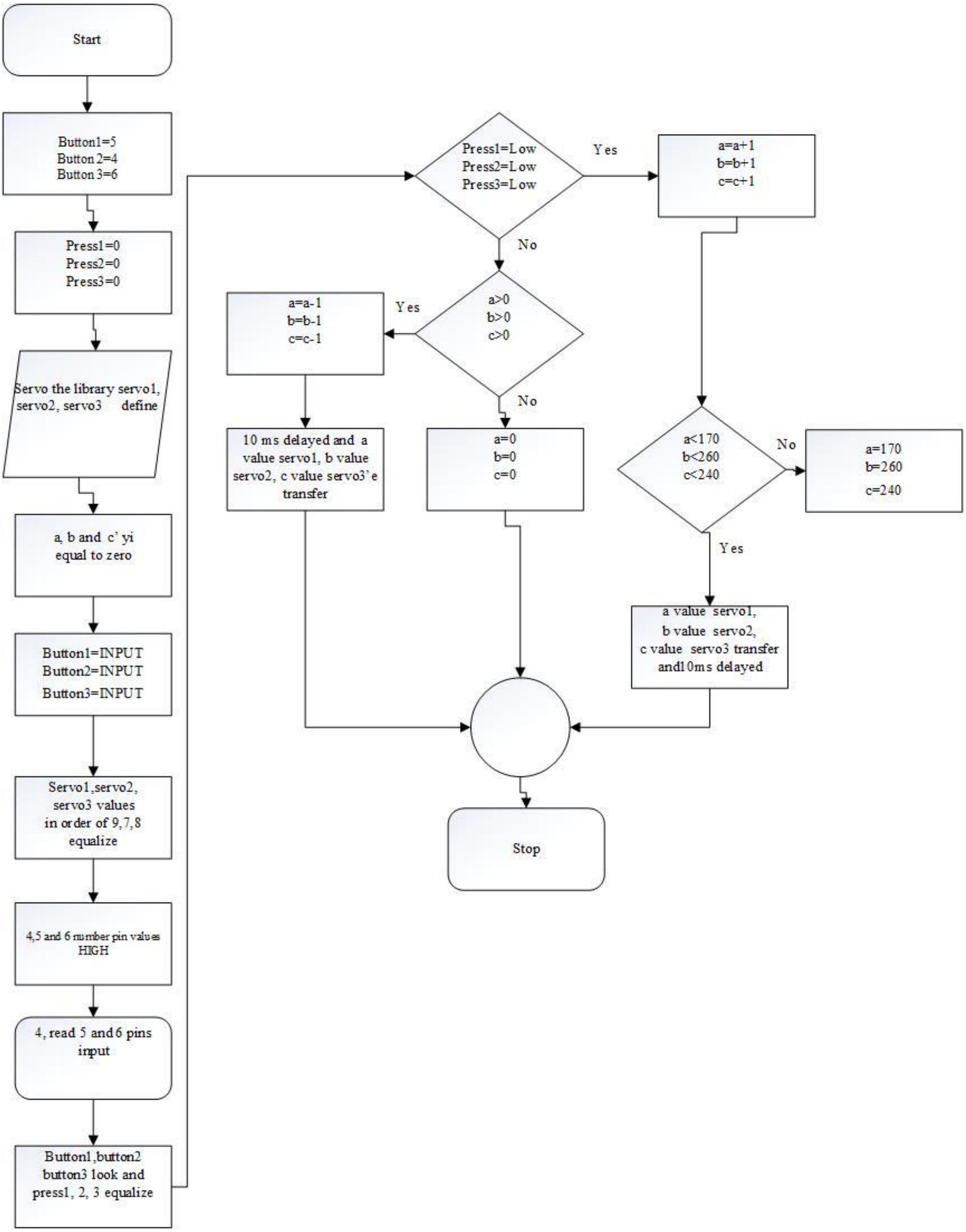

Figure 6. Flow chart of proposed program

4. Results and Discussion

In the study, ballasts at the phases L1 and L3 and a reactor with 1 kVAR at phase L2 was used as loads.

As can be seen in figure 6, Reactive power at phases L1 and L3 set to zero and active power set to be equal to apparent power. Also, Reactive power at phase L2 has been reduced to 10 VAR.

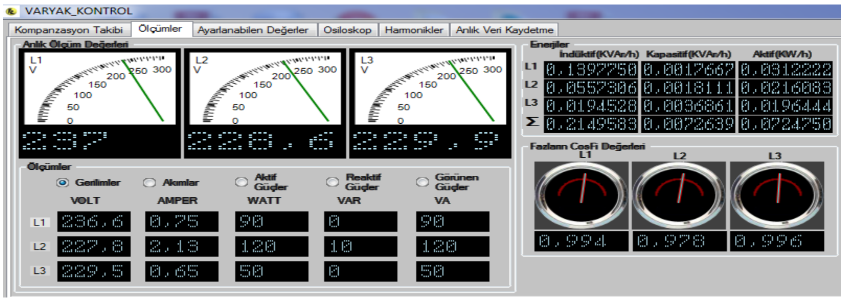

Figure 7. Computer screenshot of obtained measurements.

In the figure below a 300 W projector lamp is connected to the L2 phase. The current drawn from the mains is 2, 22 amps and the reactive power is 140 VAR
.

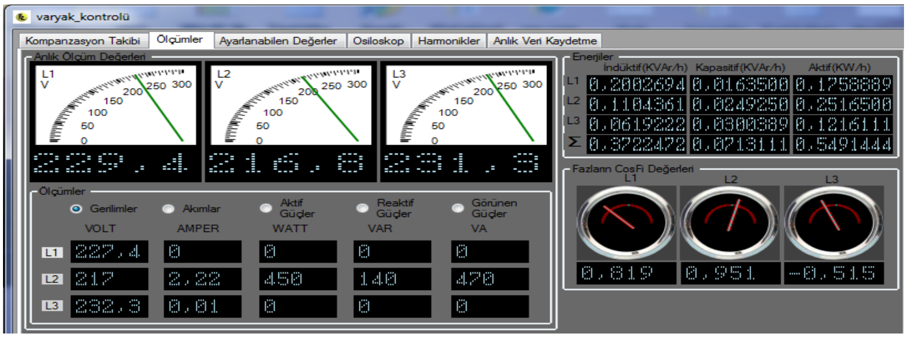

Figure 8. Computer screenshot of obtained measurements.

In the figure below is seen the compensated state of the L2 phase. The current drawn from the mains is reduced to 1, 89 amps and the reactive power is reduced to zero VAR
.

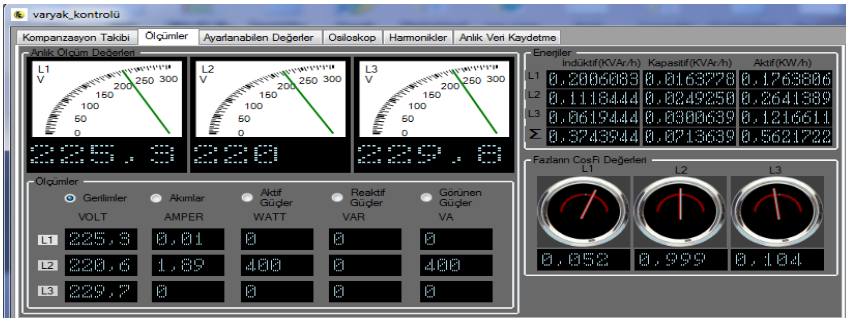

Figure 9. Computer screenshot of obtained measurements

The values obtained through adjustable auto-transformer (variac) controlled technique are presented in the Table I. In very low-power loads, the current drawn from the mains was increased by 0,25 amps by means of variac. The current drawn from the mains when the projector lamp and shunt reactor were connected was reduced and the reactive powers were reduced completely to zero. Coefficient of power ranged from 0, 98 to 1. The reactive power of the Variacs was also obtained from the connected condensers.

Table 1. The values obtained through the variac controlled technique.

Load	Power (W)	Reactive Power without compensation (VAR)	Reactive Power with compensation (VAR)	Grid current without compensation (A)	Grid current with compensation (A)
Projector lamp	**450**	**140**	**0**	**2,22**	**1,89**
Shunt reactors	1000	400	**0**	4,99	**1,66**

Ballast, projector lamp and shunt reactor were used as loads in the variac technique. Loads were single phase and connected to different phases. As show in the flow chart given in figure 10, I1 current is reduced to about 2 A to 0,75 A, I2 current is reduced to about 5 A to 2,13 A, I3 current is reduced to about 1 A to 0,5 A.

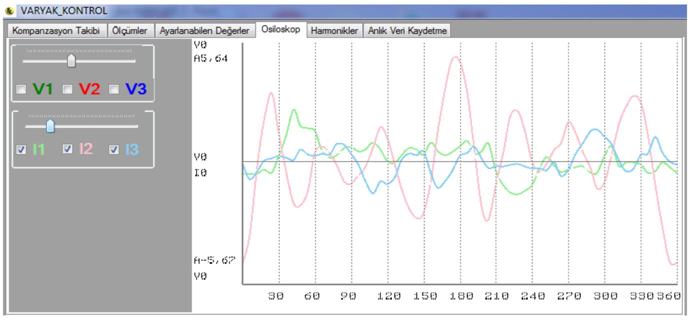

Figure 10. Compensation instantly current graphics.

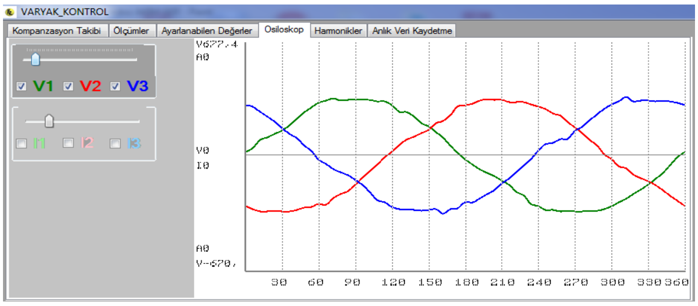

Figure 11. Compensation instantly voltage graphics.

Of the three- phase voltage curves are shown in Figure 11 at runtime. Measurement, of Kael in company is used communication software [19].

Table 2. Comparisons of the technical commissioning of the Capacitor

Characteristic	Switched Capacitor Contactor	Switched Capacitor thyristor	Switched Capacitor Variac
Cost	Depending on the number of stages is high	Depending on the number of stages is very high	(More suitable than the other applications
The area covered by	Normal	Small thyristors but lots of large capacitors have much volume	Big variac but smaller than the others
Number of Stages	6-12	6-12	1-3

Noise	Short period of contact input	Low levels	Variac sounds noise when motor is exposed short and big voltage applied to motor
Risk	Risk of sticking and giving reactive current continuously	--------	There is no risk of sticking but brushes frazzle over time
Switching Time	A few seconds	Very fast milliseconds	Slower than thyristors, faster than contactor

Input capacitors circuit techniques were compared in Table II present in some properties. System requirements as appropriate, considering these techniques can be selected. Enter the circuit expert loads very fast, controlled technique is considered to be appropriate for other loads Variac.

Power coefficients of all phases are made as shown in Table III. Reducing the number of stages provided by this study and contactor problems has prevented a drawback that remain adherent. 3.5 kVAR in a test prepared in this study was designed to provide compensation circuit for a system. Speed and position control of servo motors are made. Total Reactive current is reduced. The starting point for the rotation of the servo motors can be set to 360 0.

Prepared for use in all kinds of loads will be provided with a comprehensive software servo motors. The study is expected to contribute to energy efficiency and the use effectively of research to be conducted.

Table 3. Measurements taken in this study

Measured Values	L_1	L_2	L_3
Voltage Values (V)	235,8	227,9	231,4
Current Values (A)	0,77	2,06	0,64
Active Power Values (W)	90	120	50
***Reactive Power* Values (Var)**	0	10	0
Apparent Power Values (VA)	90	120	50
CosFi Values	0,999	0,978	0,996

5. Conclusions

As a result of the variac controlled compensation technique;

- Condensers can be connected to the circuit by means of Variacs.
- It is possible to obtain reactive currents with different values by altering the voltage exposed to condensers.
- Variacs draw reactive current by displaying a coil effect. However, the condenser connected to the relevant variac can also meet this reactive current.
- Variac controlled condensers can be easily activated and deactivated without a pause.
- Variac shafts were spun by a servo-motor.
- Reactive powers were reduced to zero in the compensation made with Variac.
- Changes in the Variac input voltage do not affect the output voltage.
- That Variac output voltage does not change can prolong the life of the condenser.
- Variac technique can easily be applied in structures with unbalanced inductive loads.
- The carbon brush placed on Variac coils should be checked for abrasion.
- The risk of being conjoined that is present in contactors is not present in Variacs.
- The number of stages was reduced by the use of Variac technique.
- Even if the size of a variac is big, the number of stages is reduced, thus reducing the board size.
- RGKR is not needed in the variac technique. Values can be monitored by the use of a multimeter.

- By measuring instant current and voltage values it can be possible to use the variac technique for various inductive loads.
- Reducing the number of stages lowers the expenditure. Various reactive powers were obtained from one capacitor by means of the Variac technique.

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