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Power factor improvement using silicon based switching devices for changing load parameters

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ABSTRACT

Systems power factor provides information on how effectively it uses the electrical power being provided to hold out real work. Losses rise as a results of poor power factor, and therefore the utility is penalized. In general, inductive loads, which are reactive in nature, make up AC loads. As a result, loads require and consume reactive power from the supply source which leads to excessive voltage drop in the line if they draw a lot of lagging current from the source, which could potentially result in the line's voltage collapsing if the drop is too high. When inductors cause a phase difference between voltage and current, the information is sent to the micro-controller, where the program takes control and activates the right number of opto-isolators interfaced to the triac silicon-based semiconductor device at its output to bring shunt capacitors into the load circuit to improve power factor to the desired range Semiconductors such as silicon or germanium are generally used for making triac. The most commonly used is silicon, due to its high abundance and the fact that it can operate at a higher temperature than germanium.

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1. INTRODUCTION

In general, AC loads are inductive loads that are reactive in nature. Inductance and capacitance are other circuit factors that control current flow [1]. The majority of industrial loads are inductive, which unnecessarily burdens the system by pulling lagging current. An electric network must maintain a constant voltage profile and create lossless power systems [2]. The traditional way to balance reactive power is to use a capacitor bank. When there is simply a resistive load in a circuit, the power factor is one, but when there is also an inductive or capacitive load, it is less than one. Due to higher power at the utility grid end, the generation and transmission costs rise when the power-factor is less than unity. As the load changes continuously, real-time reactive power adjustment is necessary. When this occurs, a fixed capacitor may overcompensate, causing an over voltage at the load end [3]. Therefore, a quick-acting device that can improve power factor and manage reactive power is required; this is where flexible alternating current transmission system (FACTS) devices come into play [4]. The FACTS device sometimes referred to as the flexible AC transmission system device, utilized external circuits, including semiconductor devices, to produce regulated output. The STATCOM, static synchronous series compensator (SSSC), and static VAR compensator (SVC) devices are the most well-known ones. In this project, controlled output for power factor enhancement is achieved by using a SVC device [5].

Shunt compensation circuits, or SVCs, are employed for regulated compensation. The SVC devices use semiconductors like thyristors and triacs for controlled switching action and a reactor or capacitor to compensate for reactive power. The following SVC configurations are possible: thyristor-controlled reactor (TCR) and fixed capacitor combination; thyristor switched capacitor (TSC) and TSC combination; TCR and TSC combination. Reactive power is produced, when necessary, by thyristor-controlled capacitors or fixed capacitors, while surplus reactive power is absorbed by TCR's [6].

A shunt-connected capacitor with a bidirectional thyristor valve to offer binary switching operation of the capacitor in either entire or zero conduction of the shunted capacitor with the line is known as a thyristor switched capacitor [7]. The thyristor valve and capacitor make up the TSC as shown in Figure 1. The capacitor is connected in series with the thyristor circuit for controlled compensation. Typically, a small reactor serves as a surge current limiter during abnormal conditions. These reactors can aid in preventing resonance by adjusting the system impedance. The capacitor switches when the voltage across the thyristor is zero (minimum), and under these circumstances, the capacitor is analogous to a capacitor that is either connected to or disconnected from the line [8]. Thus, a number of parallel TSC branches (banks) are used to handle the current variation.

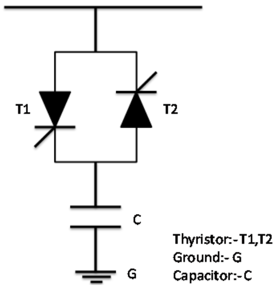

Figure 1. Thyristor switched capacitor (TSC)

2. METHODOLOGY

The Figure 2 shows the block diagram of power factor improvement using silicon-based switching device for changing load parameters. The block diagram mainly consists of 2 components which are monitoring component and TSC circuit. The system displays the power factor according to changes in the load parameters. Arduino pins 10, 11, 12, 13 connect to the triac and opt isolator combo circuit. Through this pin, a pulse signal is sent to the triac port to enable its operation. Pins 9 and 10 of the Arduino are connected to the PZEM module to obtain data such as voltage, current and power factor [9]. The resistive load is connected in parallel and the induction coil is connected in series with the resistance circuit. The TSC circuit is connected in parallel with the load component to compensate for the shunt. The input voltage is connected to the PZEM module and the load current is connected to the current transformer of the module which is used to measure the power factor of the system [10]. The module works like this. When the circuit is powered, the indicator lights up and display the power factor. When an inductive load is connected, the load parameters change [11]. System settings can be viewed in the PZEM module [12]. An inductive load causes the current to lag behind the voltage, lowering the power factor. This change is detected by the microcontroller. Depending on the value of the power factor, apply the logic of the program and activate the required number of triacs to break the capacitors in the circuits [13]. The capacitor discharges and brings the current in phase with the voltage waveform to improve the overall power factor of the system [14].

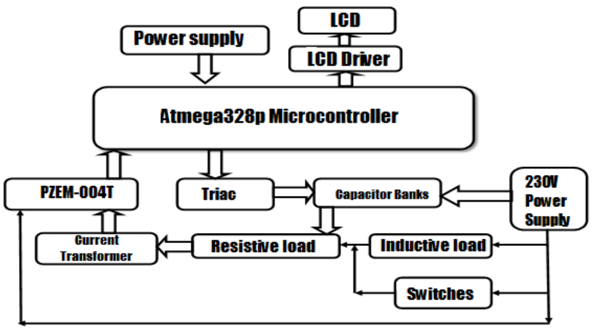

Figure 2. Block diagram of power factor improvement using silicon-based switching

3. WORKING MODEL OF TSC SYSTEM

The Figure 3 shows the working model of power factor improvement using silicon based switching device for changing load parameters (TSC system). When the system is turned on the power factor of the resistive load is displayed on the liquid crystal display (LCD). The change in load parameters is achieved by switching the inductive loads. When the power factor decreases the information is sent to the Arduino by the PZEM module [15]. When the power factor decreases to a certain level the microcontroller triggers the triac circuit to bring the capacitor in shunt with the load [16]. The capacitor decreases the phase difference caused by the inductive loads which improve the power factor of the system [17]. The power factor improvement is controlled with the help of a microcontroller to avoid overcompensation. The change in power factor is displayed in the LCD as shown in Figure 4.

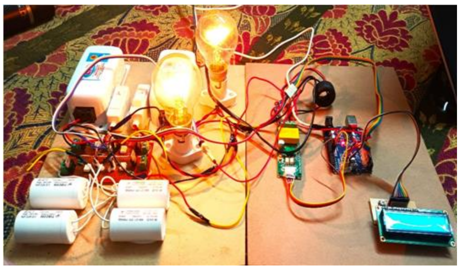

Figure 3. Hardware model of TSC system

Figure 4. Hardware model output

4. RESULTS AND DISCUSSION

As a result, the experiment carried out for changing load parameters in a single-phase ac system. Table 1 shows the power factor of the circuit with and without TSC system for different load combination. The Figure 5 shows graphical represents of power factor with and without TSC. The power factor without TSC is less than 0.85, which is due to the presence of inductive loads [18]. The inductance opposes the change in current that causes the current to lag with respect to the voltage, causing a lagging power factor [19]. If the power factor is below the required range, the system efficiency will decrease. The power factor should be in the range of 0.85 to 0.95 to maintain system stability [20]. The TSC system maintains the power factor in required range therefore achieving improved and stable power factor.

Table 1. Performance of power factor improvement using silicon-based switching device

S. no	Loads	Vin (volts)	Iout (amp)	Power factor	
				(Before correction)	(After correction)
1	R1	249 V	0.92 A	0.93	NIL
2	R1+L1	250 V	0.64 A	0.76	0.93
3	R1+L1+L2	251 V	0.62 A	0.59	0.95
4	(R1‖R2)	250 V	1.22 A	0.95	NIL
5	(R1‖R2)+L1	251 V	0.49 A	0.66	0.96
6	(R1‖R2)+L1+L2	252 V	0.56 A	0.36	0.89

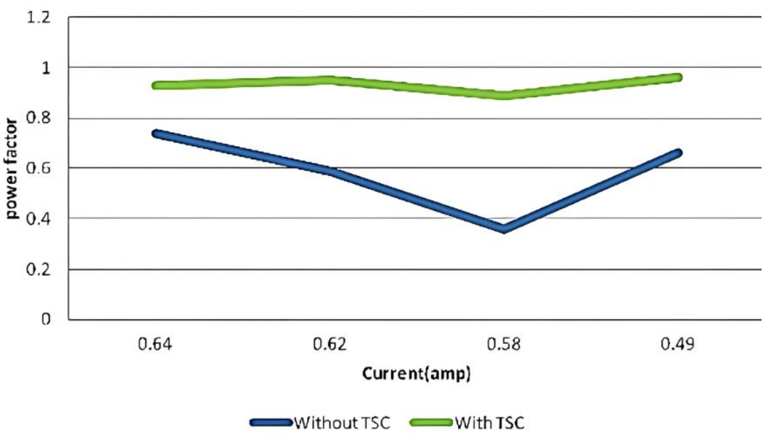

Figure 5. Graphical representation of power factor with and without TSC

Table 2 shows the reactive power of the system with and without TSC. When TSC is not used then the voltage drop across the load is equal to the supplied voltage [21]. The reactive power is calculated by (1).

$$Q\ (reactive) = V \times I \times \sin\theta \tag{1}$$

Where, 'Q' is the reactive power in VAR, 'V' is the voltage in volts, 'I' is the current in amperes, and 'θ' is the phase angle in degrees.

Table 2. Reactive power before and after compensation of the single-phase AC system

S.no	Vin (volts)	Vout (volts)	Iout (amp)	Phase angle in degrees (before correction)	Phase angle in degrees (after correction), (degrees)	Reactive power (before corrections), (VAR)	Reactive power (after corrections), (VAR)
1	250 V	309 V	0.64 A	40.53	21.56	103.97	72.67
2	251 V	284 V	0.62 A	53.84	18.19	125.6	54.96
3	251 V	291 V	0.49 A	48.7	16.26	92.39	39.92
4	252 V	259 V	0.56 A	68.89	21.12	136.35	54.12

Power factor of the system is obtained from (2) which varies for changing load parameters:

$$Power\ Factor = \cos\theta \tag{2}$$

when TSC is used due to shunt capacitors the voltage is boosted and output voltage is more than supplied voltage. Similar to the above case the reactive power can be calculated. When compared the reactive power with TSC system is less than the system without TSC [22].

The Figure 6 shows graphical representation of reactive power with and without TSC. The reactive power of the system with TSC is less than that of the system without TSC [23]. This shows that the system with TSC has more efficiency as most of the power utilized in the system is real power and very less amount of power is consumed by the reactive components during change in load parameters [24], [25]. Through this power factor and reactive power control can be achieved.

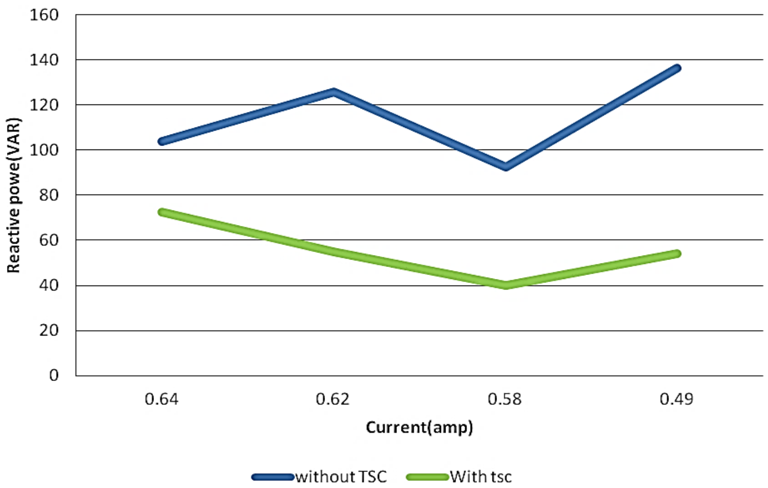

Figure 6. Graphical representation of reactive power with and without TSC

5. CONCLUSION

Power factor improvement using TSC is required for maintaining the system stability by controlling the power factor of the system. Use of capacitor banks makes it cost effective and triac switching provides us controlled compensation. Compared to other compensation methods the TSC provides fast switching action which can be used for continuous systems for maintaining constant power factor during change in load parameters. The above provides us the power factor value of single-phase ac system with and without TSC, demonstrating that the power factor improvement using silicon based switching device provides stable and controlled power factor value at change in load parameters.

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