Remotely Controllable Regulator Connected in Series with Resistive and Inductive Loads

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ABSTRACT

This work presents a simple design and implementation of a series connected remotely controllable regulator which can be used for both resistive and inductive type loads driven by AC power. Commonly available remote controlled regulators require access to both live and neutral connections. The designed regulator enables the single line power controlling which offers a high level of convenience to the user. The power supplied to the load is controlled by a Triac, because it can control the current flow over both halves of an alternating cycle. The trigger on the gate terminal is set by a diac. The active components of the regulator are powered by a Switch Mode Power Supply (SMPS) using the voltage drop across the Triac. Radio Frequency (RF) remote control module controls the device and improved user satisfaction at a much better range. RF does not require the typical IR point-and-shoot action. The regulator includes a timer which enables the user to control both the level and the period of power. A seven segment display unit is included in the design to indicate the supplied power level and the timer setting. PICmicro® 16F873 microcontroller is used to drive the system and the timer. When compared with remote controlled regulators which require alternative additional electrical wiring system, the designed regulator is much more user friendly. It has many advantages such as low power consumption, small in size and low manufacturing cost and etc.

Keywords: *Timer; RF; SMPS; Remote;Display; PIC*

1. INTRODUCTION

Ceiling fans speed controllers and light dimmers are commonly found regulator types for controlling inductive and resistive loads. Remote control regulators add more comfort to everyday living since they facilitate control of devices from a distance without having to move around [1]. Remote controlling systems are very convenient and durable systems irrespective of usage.

The aim of this work is to design a series connected remote controlling regulator system for resistive and inductive loads. Since this is a single line power controlling device it can easily replace manual regulators without changing the electrical wiring system.

This system contains a RF remote with much better range, a regulator with a seven segment display unit. PICmicro® 16F873 [2] is used to control the power supplied to the resistive and inductive loads and the seven segment display unit.

The advantage of this regulator is that all the active components of the device are powered by a single line without using an additional electrical wiring system with neutral connection. A Switch Mode Power Supply (SMPS) is used in the device to avoid the use of a bulky transformer. SMPS converts electrical power more efficiently than a conventional transformer power supply with minimum power dissipation.

2. PROCEDURE

2.1 Power Controlling

The power delivered to the load is controlled by using BT1395 Triac [3]. By applying a trigger pulse to the gate terminal of the Triac, it can be set to control the phase angle of an AC cycle. This allows controlling the percentage of current that flows through the Triac to the load [4]. The trigger on the gate terminal is set by diac which is connected to the series combination of the resistor and capacitor. When the voltage across the capacitor increases and reaches to the break over voltage of the diac, the diac breaks down and the capacitor discharges through the diac, producing a sudden pulse of current which fires the Triac into conduction. The phase angle at which the Triac is triggered is controlled using the PICmicro® 16F873 by controlling the charging rate of the capacitor. The MOC30216 optocouplers are used to isolate the controlling circuit from main power. Each time the Triac is turned on, the load current changes very quickly in few microseconds from zero to a value determined by the resistance of the load and the value of the voltage for that instant of time. This transition generates Radio Frequency Interference (RFI). An L-C RFI suppression network is used in the design to minimize the RFI.

2.2 Switch Mode Power Supply

A SMPS is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. The main advantage of using a SMPS is its high efficiency. Because the switching transistor dissipates little power when it is outside of its active region (i.e., when the transistor acts like a switch has a negligible voltage drop across it). Other advantages include smaller in size and lighter in weight (from the elimination of low frequency transformers which have a high weight) and lower heat generation due to higher efficiency.

The SMPS was designed so that it could be operated using the voltage drop across the Traic. The two windings fly back transformer was used in the SMPS. First AC voltage was converted to DC using 1N4007 and 2·2μF buffering capacitor. Using self-oscillating circuit power transistor was switched at a high frequency. The high frequency pulse generated by the transistor was then fed into the switching coil of the transformer. Two primary windings of the fly-back transformer act as magnetically coupled inductors. MJE13002 transistor which is used for high–voltage, high speed power switching in inductive circuits was used in this design [5]. The output from the secondary winding of the transformer was passed through a high speed switching diode 1N4848 and a capacitor for rectification. Circuit was designed using minimum number of components to reduce the manufacturing cost.

2.3 The Timer

The regulator incorporates a timer to turn off the power after a given period of time. It was designed using the Timer1 Module of PICmicro® 16F873 microcontroller. The microcontroller was programmed to issue a signal to the Triac driver to stop after a certain period of time to cut off the power delivered to the load. The cut off time is determined by the Timer1 module by counting up to a specific value which has been loaded into a register of the microcontroller.

2.4 7-Segment Display Unit

To show the supplied power level and the timer settings, a 7-segment display was designed using a 74HC595 shift register. Two seven segment display units were used in this design to display two numbers. One of the 7-segment units was always turned “OFF” during this operation. But it was designed to operate very fast by using two BC547 transistors as switches, so that human eye can’t identify the blinking of two 7-segment units. Two BC547 transistors were controlled by the PICmicro® 16F873.

2.5 Remote Control Unit

A four button 315MHz RF transmitter was used to control the regulator. The transmission distance of the remote control unit is about 50m-100m in open field. The four buttons on the remote control produce four data bits to the receiver board output pins which correspond to each of four buttons.

3. RESULTS AND DISCUSSION

The designed regulating system was tested for both ceiling fans and incandescent lights and it functioned perfectly for both resistive and inductive loads. The advantage of using SMPS is that it provides great efficiency. The voltage drop across the triac was used to operate the necessary circuits so no external power is used in this design.

The designed regulator was connected to a ceiling fan and the power consumption was measured with the rotation speed of the ceiling fan. The power consumption of manually controlled capacitive type and inductive type regulators were also measured with the rotation speed for the same ceiling fan for comparison. The polynomial fits for power consumption against rotation speed for all three types of regulators for the inductive load (ceiling fan) are shown in Fig. 1.

The power consumption of the designed regulator, inductive regulator and capacitive regulator were measured with the intensity level of the incandescent bulb. The polynomial fits for power consumption against intensity for all three types of regulators for the resistive load (incandescent bulb) are shown in Fig. 2.

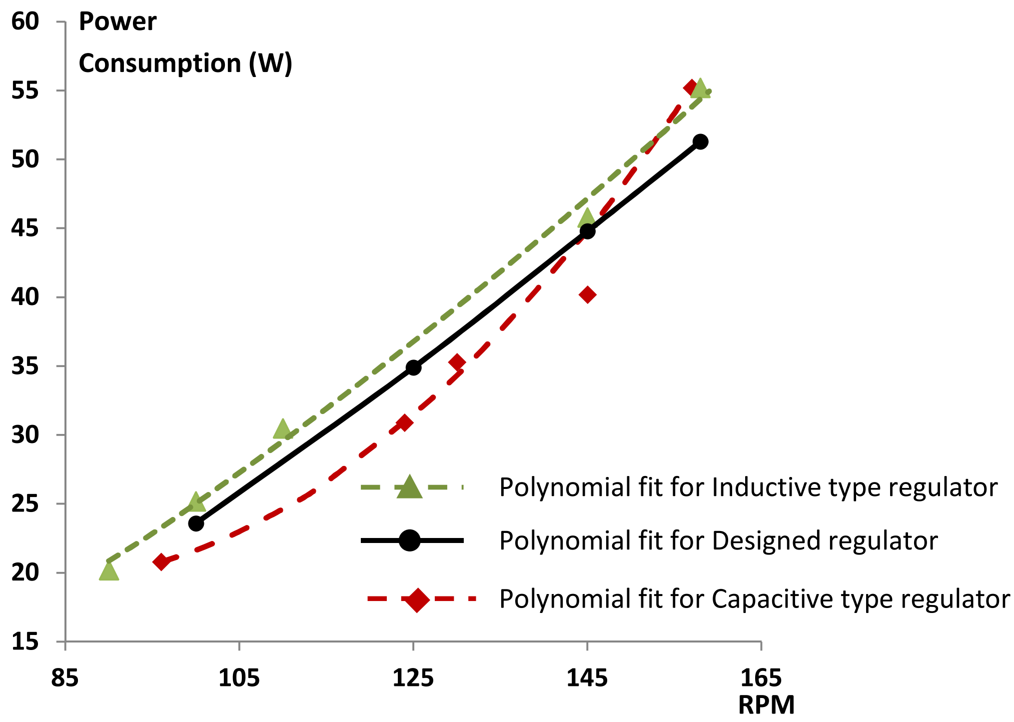

Fig. 1: The polynomial fits for the power consumption Vs the rotating speed for different type of regulators for inductive load

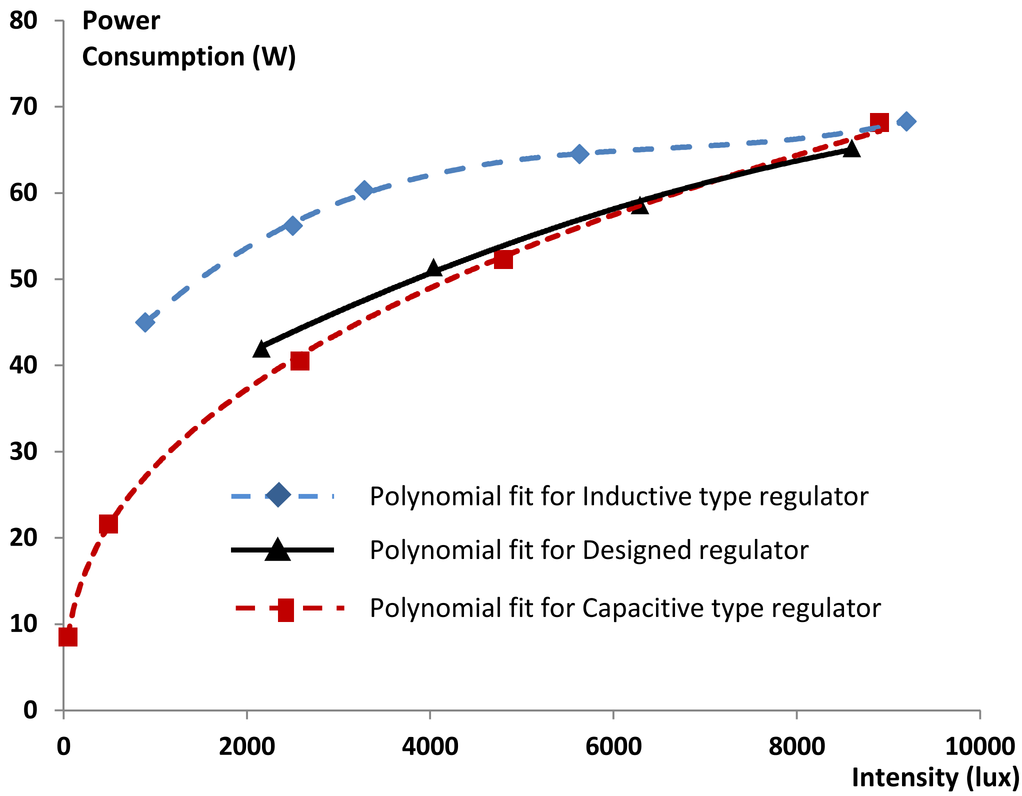

Fig. 2: The polynomial fits for the power consumption Vs intensity level for different type of regulators for resistive load.

According to the graphs, the variation of power consumption Vs RPM for inductive load and the power consumption Vs intensity for resistive load for designed regulator is more linear than the other compared regulators. For high rotational speeds of the ceiling fans and the high intensity levels of incandescent bulb, designed device works more efficiently than capacitive and inductive regulators which are tested.

Table 1: The voltage drop across the triac and the load for both inductive and resistive loads

Power Level	Supply voltage (V_{rms})	Voltage drop across triac (V_{rms})		Voltage Drop across load (V_{rms})	
		Inductive load	Resistive load	Inductive load	Resistive load
1	225	150	118	178	132
2	225	121	83	200	153
3	225	44	55	215	180
4	225	25	28	225	205

It is evident from the Table 1 that the voltage drop across the triac is more or less the same for both inductive and resistive loads at power level 4 which is the maximum level. However, at power level 4, the voltage drop across the load is almost the same as the supply voltage for inductive loads but it is little less than the supply voltage for resistive loads.

There is no need to change the programme to achieve desired power levels. The user can manually adjust the power levels using the pre-sets. With a little modification to the device it can be programmed to operate using IR as well.

4. CONCLUSIONS

The main problem of developing a single line remotely controllable regulator is to power up the active devices without access to the neutral. The idea of using the voltage drop across the Triac to operate SMPS was very successful.

From the polynomial fits drawn for the capacitive type, inductive type, and designed regulators, the variation of power consumption Vs RPM is much linear for the designed regulator than the other compared ones. The power consumption of resistive load for the designed regulator also shows much linear variation than the capacitive type, and inductive type regulators.

The 4 power levels of the designed regulator were tested using different type of celling fans and incandescent bulbs with different wattages. The power controlling unit, timer and the display unit worked perfectly.

Manual regulators can’t be directly replaced by most commonly available remote control regulators because those regulators require alternative electrical wiring system to operate.

But the designed device can be operated using single line so any mechanical regulator can be replaced easily with this remote controllable unit.

This device can be modified to control several channels simultaneously by introducing more Triacs and some other peripherals.

This device is isolated from the main power supply using a SMPS and the optocouplers so the controlling unit is very well protected.

The designed device uses a SMPS. Most of the remote controllable regulator designs available in the market use a step-down transformer to reduce the 230 V AC to a desired level of low voltage AC, and then converted it in to DC. The efficiency of this kind of power supply is lower than SMPS. SMPS is much smaller in size and lighter in weight. Its heat generation is low due to higher efficiency and it offers better performance over the device.

RECOMMENDATION

Since active components can be powered by using SMPS, other power controlling methods such as pulse width modulation is interesting to be tested for the series connected remotely controllable regulators.

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