

APPLICATION OF RCSTL FOR MITIGATION POWER CAPACITOR SWITCHING TRANSIENT

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Abstract: This paper presents the study of a new resistive capacitor switching transient limiter (RCSTL) to reduce the risk of losses due to the power capacitor switching transients. The RCSTL consist of the three limiting resistors, a three-phase full bridge diode rectifier, a thyristor and a three-phase coupling transformer. The limiting resistor is connected in series with the capacitor bank and the thyristor is installed at DC side of the diode rectifier. During the processes of the capacitor bank energising, the thyristor is in OFF state so that the secondary side of the coupling transformer behaves as open circuit due to which high impedance with the transformer's magnetic reactance is in parallel with the limiting resistor which is in the series in the capacitor bank. Under such condition the limiting resistor restrain the capacitor switching transients. The control system triggers the thyristor and the coupling transformer acts as short circuit in steady state condition. The limiting resistor are bypassed by coupling transformer and therefore RCSTL has no significant effect on circuit. To describe the different operating mode of proposed RCSTL analytical analysis is performed.

Keywords — Potential transformer, LM358, Thyristor, coupling transformer, MATLAB software

I. INTRODUCTION

Nowadays power factor correction is very advantageous in decreasing the power loss in feeders and transformers, reducing system voltage drops, increasing capacity of system etc. Generally shunt capacitors are used to increase power factor of the power systems. The capacitor banks may be switched in and out several times during a day to maintain the system loads and the voltage profile constant and to adjust the system power factor. This reduces the lifetime of the capacitor bank and can damage the electromagnetic switches such as circuit breaker and it also affects the customer's electrical apparatus. There are several techniques implemented to mitigate the capacitor bank switching transients. The surge current needs to be totally discharged so that system grounding issues must be taken into account in this method. Many approaches are based on zero-voltage closing control in which the capacitor bank energised when voltage across the switching contactors are almost zero. This method utilise power electronic components and additional control system that increase the complexity and also the cost of the system and thus they have less economic justification. When the capacitor bank energized, the capacitor transients are limited by inserting a fixed limiting reactor in the line. This technique seems to be simple and less expensive it might be result in series resonance occurrence. This method is designed only for the high voltage application,

II. PROPOSED SYSTEM

The block diagram of the proposed system for mitigation power capacitor switching transients is shown in fig.1

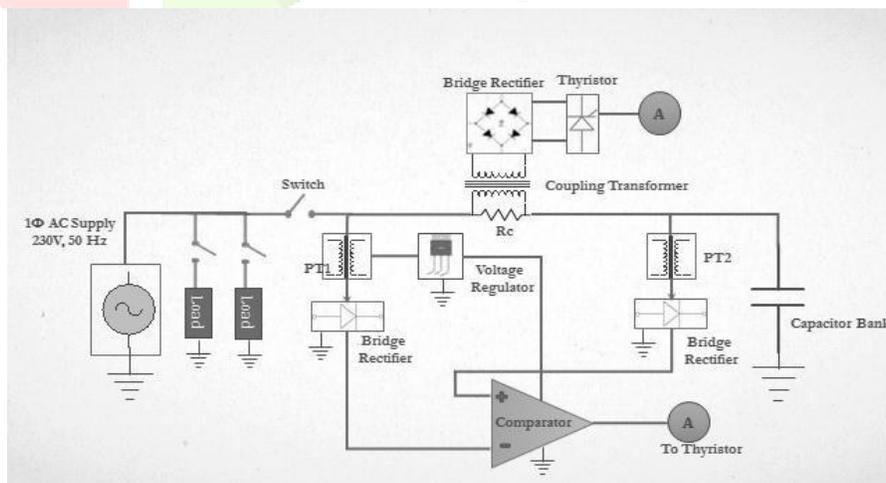


Fig.1: Block Diagram of the Proposed System

Proposed system is composed of a single-phase coupling transformer, a single-phase full bridge diode rectifier, limiting resistors, and a thyristor. The limiting resistors are connected in series with the line and are parallel with the primary side of the coupling transformer. The basic function of the coupling transformer is to bypass the limiting resistors in the steady-state condition. Moreover, the Peak Reverse Voltage (PRV) and the current ratings of the diodes as well as the thyristor could be adjusted by regulating the turn ratio of the coupling transformer. The secondary windings of the single-phase coupling transformer are wye-connected and are connected to the single-phase full bridge diode rectifier. The thyristor is installed at the DC side of the bridge rectifier. The control circuit is composed of two low power single-phase potential transformers (PT), two low power single-phase full bridge diode rectifiers, voltage regulator and an operating amplifier (Op-Amp). The main function of the control system is to measure the voltage difference between the source and the capacitor bank. When the transient time interval is finished and the capacitor bank is almost charged, the control system triggers the thyristor. When the thyristor turns on, the limiting resistors are bypassed by the single-phase coupling transformer. The gate pulse is built using a resistive-inductive (R-L) circuit to decrease the power loss of the thyristor gate. The voltage supplied to the negative terminal of the comparator is reduced through a voltage divider circuit (Rtuning) to compensate the instantaneous voltage drop of the coupling transformer as well as to adjust the bypassing time of the limiting resistors. The outputs of the single-phase PTs are fed into the input terminals of the Op-Amp. The Op-Amp is supplied by the voltage regulator from the DC-side voltage of the primary PT. In Fig. VCC denotes the comparator power supply pin and LM7805 is the voltage regulator. In case of control system malfunctions or the thyristor failures, the limiting resistors cannot be bypassed. Thus, the steady-state power losses of the RCSTL would increase considerably. In addition, the capacitor bank terminal voltage and the capacity of the capacitor bank reduce in such conditions. To insure the reliable operation of the RCSTL and to remove the aforementioned problems, overload sensors are added in series with the limiting resistors as shown in fig 1. If the control system fails to bypass the limiting resistors, the thermal overload sensors trip the main mechanical breaker.

III. COMPONENTS SELECTIONS

- **Bridge rectifier:**

In bridge rectifier four diodes are used. These are connected as shown in the circuit diagram. The four diodes are connected in the form of a bridge to the transformer and the load as shown.

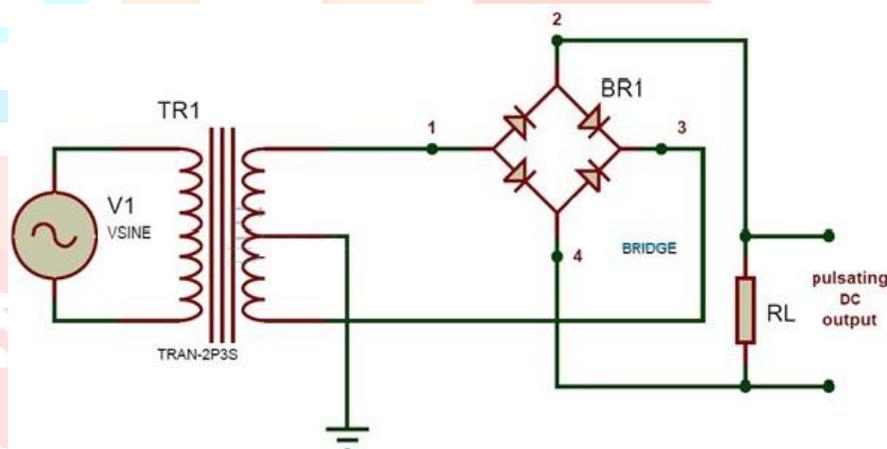


Fig. 2: Bridge rectifier

The working of a bridge rectifier is simple. The circuit diagram of bridge rectifier is given above. The secondary winding of the transformer is connected to the two diametrically opposite points of the bridge at points 1 and 3. Assume that a load is connected at the output. The load R_{Load} is connected to bridge through points 2 and 4. During first half cycle of the AC input, the upper portion of the transformer secondary winding is positive with respect to the lower portion. Thus during the first half cycle diodes D_1 and D_4 are forward biased. Current flows through path 1-2, enter into the load R_L . It returns back flowing through path 4-3. During this half input cycle, the diodes D_2 and D_3 are reverse biased. Hence there is no current flow through the path 2-3 and 1-4. During the next cycle lower portion of the transformer is positive with respect to the upper portion. Hence during this cycle diodes D_2 and D_3 are forward biased. Current flows through the path 3-2 and flows back through the path 4-1. The diodes D_1 and D_4 are reverse biased. So there is no current flow through the path 1-2 and 3-4. Thus negative cycle is rectified and it appears across the load.

- **POTENTIAL TRANSFORMER**



Potential transformers are also known as voltage transformers and they are basically step down transformers with extremely accurate turn's ratio. Potential transformers step down the voltage of high magnitude to a lower voltage which can be measured with standard measuring instrument. These transformers have large number of primary turns and smaller number of secondary turns. A potential transformer is typically expressed in primary to secondary voltage ratio. For example, a 600:120 PT would mean the voltage across secondary is 120 volts when primary voltage is 600 volts. In an ideal potential transformer or voltage transformer, when rated burden gets connected across the secondary; the ratio of primary and secondary voltages of transformer is equal to the turns ratio and furthermore, the two terminal voltages are in precise phase opposite to each other. But in actual transformer, there must be an error in the voltage ratio as well as in the phase angle between primary and secondary voltages.

Fig.3: potential transformer

- **LM358 (LOW POWER DUAL OPERATIONAL AMPLIFIERS)**

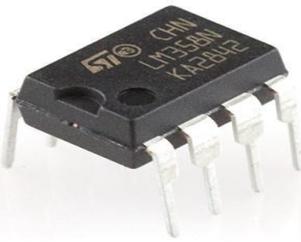


Fig.4:LM358

The LM158 series consists of two independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltages. Application are as include transducer amplifiers, dc gain blocks and all the conventional op amp circuits which now can be more easily implemented in single power supply systems. For example, the LM158 series can be directly operated off of the standard +5V power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional $\pm 15V$ power supplies.

- **THYRISTOR**

A thyristor is a solid-state semiconductor device with four layers of alternating N and P-type material. It acts exclusively as a bistable switch, conducting when the gate receives a current trigger, and continuing to conduct while the voltage across the device is not reversed (forward-biased). Some sources define silicon-controlled rectifier (SCR) and thyristor as synonymous. The first thyristor devices were released commercially in 1956. Because thyristors can control a relatively large amount of power and voltage with a small device, they find wide application in control of electric power, ranging from light dimmers and electric motor speed control to high-voltage direct current power transmission. Thyristors may be used in power-switching circuits, relay-replacement circuits, inverter circuits, oscillator circuits, level-detector circuits, chopper circuits, light-dimming circuits, low-cost timer circuits, logic circuits, speed-control circuits, phase-control circuits, etc.

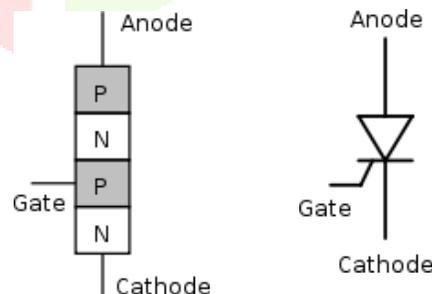


Fig.5: Thyristor

The thyristor is a four-layered, three terminal semiconductor device, with each layer consisting of alternately N-type or P-type material, for example P-N-P-N. The main terminals, labelled anode and cathode, are across all four layers. The control terminal, called the gate, is attached to p-type near the cathode.

- **COUPLING TRANSFORMER**

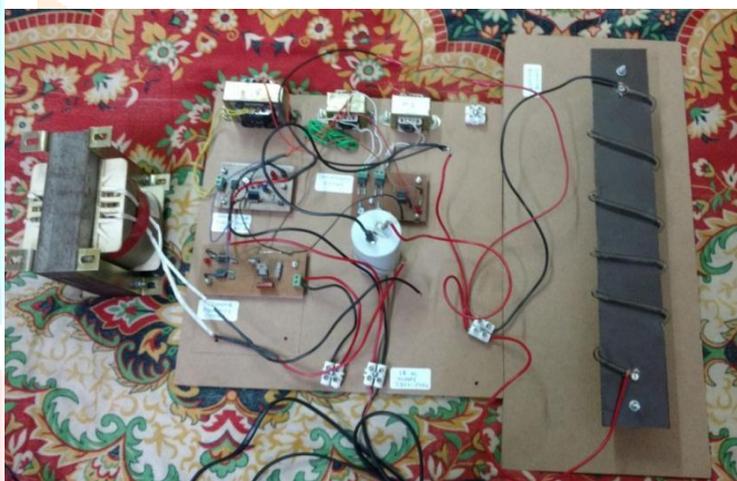


Fig.6: Coupling Transformer

Maximum kVA of each single-phase coupling transformer can be calculated by $\Delta v_{ss} \times i_{c,ss}$ in which Δv_{ss} is the voltage drop across the primary winding of the coupling transformer in the steady-state and $i_{c,ss}$ is the steady-state current of the capacitor bank. The turn ratio can be selected to adjust the current and voltage ratings of the thyristor and diodes in the single-phase full bridge diode rectifier. Furthermore, by increasing the turn ratio of the coupling Efficiency of the proposed RCSTL versus the capacity of the capacitor bank transformer, the effect of the forward voltage drops of the pair of diodes and the thyristor can be reduced. According to the operation principles of the RCSTL, the leakage inductances of the coupling transformer need to be minimised. Interleaving the windings of the transformer, minimising the number of turns, utilising appropriate core type, etc. would decrease the leakage inductances of the transformer.

IV. HARDWARE SETUP AND OUTPUT

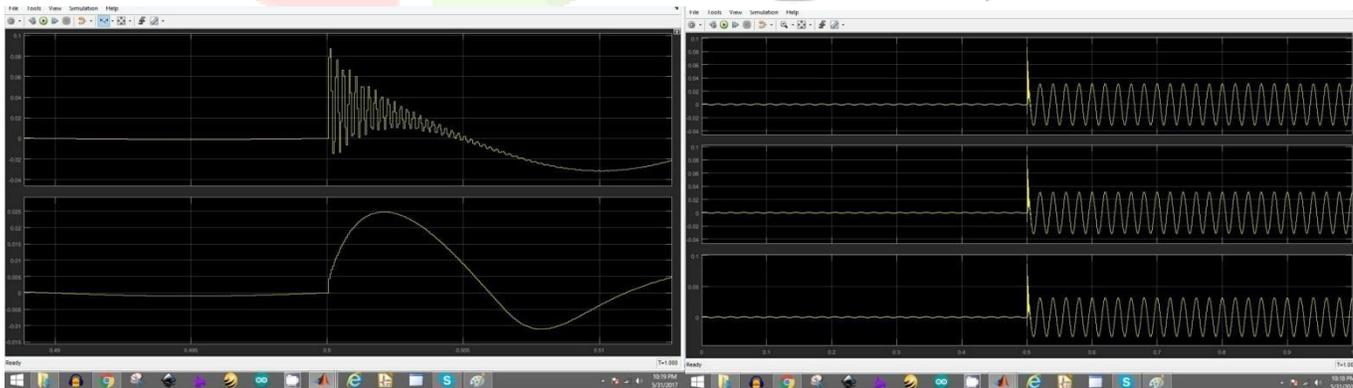
The hardware set of that proposed are shown in below



Hardware setup of the proposed system

OUTPUT

The output of the proposed system are show in below. This output are optened by using MATLAB software.



V. CONCLUSION

To mitigate the power capacitor bank switching transients, a three-phase resistive capacitor switching transient limiter is proposed. During the energisation process, the RCSTL mitigates the switching transients by utilising three limiting resistors in series with the capacitor bank. In the steady-state, a thyristor installed at the secondary side of the coupling transformer is turned on and hence, the limiting resistors are bypassed by means of the three-phase coupling transformer. Besides, a simple, reliable and fast control system is proposed to trigger the thyristor. According to the experimental results, it can be concluded that the proposed RCSTL is able to substantially suppress the energising transients. In addition, the high efficient RCSTL has almost no impact on the system during the steady-state.

VI. REFERENCES

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