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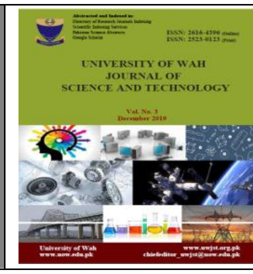

TRIAC Based Automatic Voltage Stabilizer

Muddasar Ali, Naveed Anwar, Syeda Tahreem Zahra, Aqeel Hayat, Shahrukh Zaffar and Shahid Iqbal

***Abstract*—Nowadays power demands are continuously increasing and the biggest challenge is to provide stable voltage to consumers under different load conditions. The fluctuation in nominal voltage values affect the performance of attached load. Voltage Stabilizer is a device, which is used to balance the voltages under changing load conditions. However, conventional voltage stabilizers have slow transient response with additional problem of sparking resulting from electromechanical relays. These problems are eliminated using TRIAC based automatic voltage stabilizer. Moreover, these also provide over voltage protection, overload protection and short circuit protection. TRIACs are utilized as switching devices with comparable number of transformer taps. In this research paper, a TRIAC based automatic voltage stabilizer is simulated in Proteus and then designed and implemented using PIC microcontroller. The problems of slow transient response with high sparking of relays in conventional voltage stabilizer have been successfully compensated using TRIAC based automatic voltage stabilizer. The experimental results verify the clam of high quality performance of TRIAC based automatic voltage stabilizer.**

***Index Terms*—Automatic Voltage Stabilizer, TRIACs, Microcontroller, Over voltage protection, Short circuit protection, Tap changing transformer, Under voltage protection.**

I. Introduction

VOLTAGE stabilizer is typically used to protect electrical machine from uncertain voltage levels. The standard of Automatic Voltage Regulation includes the way towards keeping up the voltage level at a predetermined level constantly. Poor and inconsistent electricity flow can occur for several reasons. There may be voltage fluctuations due to network overload or low capacity conductors used to power the building.

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M. Ali (email: muddasar.ali275@gmail.com), N. Anwar (email: naveed.anwar@wecuw.edu.pk), A. Hayat (email: aqeelhayat08 @gmail.com), S. Zaffar (email: shahrukhzaffar@gmail.com) and S. Iqbal (email: ajexkhan@gmail.com) are affiliated with Department of Electrical Engineering, University of Wah, Wah Cantt, Pakistan.

S.T. Zahra (email: stahreem94@gmail.com) is affiliated with Department of Electrical Engineering, HITEC University, Taxila, Pakistan.

Corresponding author email: muddasar.ali275@gmail.com

Even nature can be the cause here as well. For example, when a lightning strikes, a surge occurs and the voltage rises abnormally. Defective electrical devices can also cause a problem. If a device is faulty, it can fluctuate because it draws more power than required usually. Unless the electrical hardware has a programmed voltage controller, the power surges to the devices could not give much harm when device is off and on. The Advance TRIAC-based automatic voltage regulator is a device proposed to control the voltage variations. It changes the voltage level and converts it to a constant voltage level. Voltage stabilizers are widely used as part of the power field to ensure strength and control of voltages. Voltage Stabilizers are used to provide the necessary supply voltage for home and modern devices as well.

Switching from all voltage regulators to electromagnetic relays or servomotors or electronics is complete and automatically selects the tap of transformer to obtain the desired voltage to support (add) or buck (subtract) the input voltage. Relay tap changers can lose power instantly during closing and opening of relay contacts, resulting in unstable output and damage to contacts. The response time of relay based voltage stabilizer is low. Operation of this stabilizer is noisy and produces spark due to contacts of relay (makes and breaks).The servo engine has a disadvantage that the life of relay contacts is short. The response time of Servo voltage stabilizer is also lower than relay based voltage stabilizer. When line voltages are higher enough than normal supply voltages, the equipment may damage before action of stabilizer due to slower response. Solid state electronic device (utilized as a part of TRIAC Based Automatic Voltage Stabilizer) can defeat the majority of the above issues [1]. As they do not have any moving part and the output can vary from cycle to cycle. Therefore, it also reduces response time. In this research paper, hardware of TRIAC based automatic voltage stabilizer is designed to balance the voltage under different load conditions using Proteus software. The problem of slow transient response with high sparking of relays in conventional voltage stabilizer is successfully reduced using TRIAC based automatic voltage stabilizer. There will be no Arcing and Sparking as TRIACS are used instead of relays. The proposed approach is used to reduce switching losses and to get constant output voltages with

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faster switching response under several variations in voltage. TRIAC based stabilizer has key advantages like arc quenching, faster response, no friction losses, improved life of contacts and significantly constant output voltage. The results show that the voltage levels at the output side are kept with in stipulated levels when the proposed system of TRIAC based stabilizer is applied.

II. Literature Review

Voltage stabilizers have been in literature for nearly 158 years. A similar concept of Voltage controllers exist in literature but these are generally referred to as voltage enhancement, or all the more effectively 'Power Optimization'. Voltage optimization is more sought after today than at some other time, as it is on the grounds that power request is continually developing. This creates a resultant weakening of energy quality – irregular voltage which is generally too high and now and again too low. This consistent change in principle voltage harms client's electrical devices and makes them pay excessively for their electricity [2-4].

There have been many efforts design and implementation of automatic voltage stabilizers. In [5] the outlining and usage of an Automatic Voltage Regulator (AVR) with higher exactness and hysteresis was exhibited. The outline guarantees to direct 150V-273V AC variety of contribution to the middle of road scope of 215-237 volt utilizing a few taps.

One of the variant of AVR is Programmable Automatic Voltage Regulator (PAVR), which offers high exactness and suitable hysteresis. Subsequently, the circuit plan and usages are especially simple, adaptable and the productivity of this framework is adequate. To stay away from the adjustment of voltage, minimization of output wave rate and unchangeable power-voltage to the instruments are required while the load changes. It requires the support of stable voltage and fast response against the sudden difference in input voltage and load [6].

The Microcontroller based AVR is another type of AVR whose execution and outline presents a way to have distinctive outline and task in looking at accessible AVR. The uniqueness of outline is that no moving part is existing and subsequently, no support is required [7].

A simulation procedure can also be devised for an alternator demonstrating its execution qualities with and without a programmed voltage regulator (AVR) associated with it as a piece of work improved the situation Project Stage. Simulations were conveyed in MATLAB. The target of this work was to become acquainted with the impact of AVR on the framework [8].

The three-phase variant of microcontroller based voltage stabilizer comprises of incorporated control unit and circulated control unit [9].

III. Proposed Design

The fundamental building blocks for developing complete hardware incorporates a PIC 16f877A Microcontroller, a TRIAC, a 400V auto-transformer, a zero-cross detection and load voltage detecting circuit.

Operation of developed hardware mainly depends on standard of stage control of A.C voltage utilizing a TRIAC, whereas, activating (terminating) delay is controlled by PIC Microcontroller. The block diagram of TRIAC based automatic voltage stabilizer is shown in *Fig. 1.*

Microcontroller will naturally control the entire hardware and go about as control unit. Power supply gives consistent 5V DC as input voltage to microcontroller and furthermore to the thyristors. Microcontroller peruses the line voltages utilizing potential transformer (given to the ADC of microcontroller) and afterwards change the tapping of transformer utilizing solid state device (TRIAC).

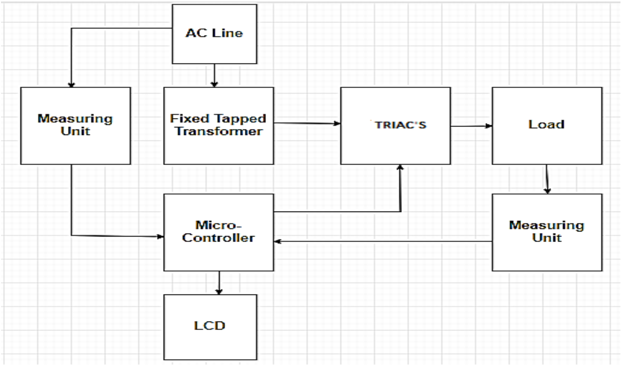

Fig. 1. Block diagram of TRIAC based voltage Stabilizer.

IV. Triggering Of Triac

Now TRIAC is a gate controlled bidirectional device. It needs a pulse to conduct, when the pulse is given at its gate terminal, it starts conduction. Thus, in this way output is controlled by delaying the pulse. For triggering it needs a reference from where it will start delay. For a 50Hz signal of sine wave, the triggering time lies between 0 and 10ms or it can be 0 to 180 degree. The phenomenon can be seen from *Fig.2* [10-11].

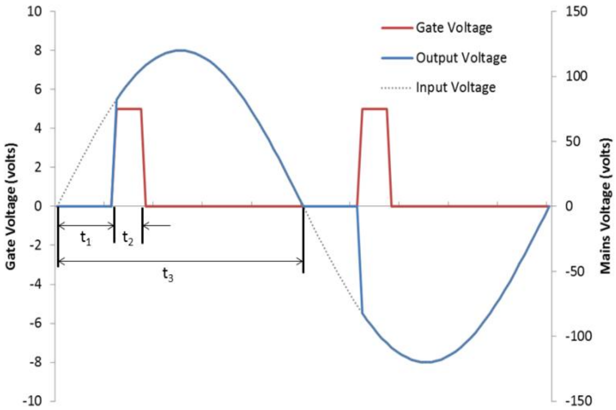

Fig. 2. Triggering of TRIAC.

V. Hardware Implementation

A. Voltage Measurement

The input and output voltages are sensed and are fed to the microcontroller. Terminal voltage of the regulator is always sensed and it is fed back to the microcontroller. The voltages are stepped down to 6V and then rectified through the bridge rectifier [8-9]. Two capacitors 0.1 μf and 47 μf, which are connected in parallel, are used to filter these voltages. A 10kΩ resistor and a variable resistor of 10kΩ are connected with these capacitors; the variable resistor is regulated when line voltages are 220V.

B. *Current Measurement*

The device to develop is based on the gradual increase of input voltage to reduce or minimize the motor current at startup. Each motor has its own current rating, depending upon its power rating. Now, they should be certain limit from which current cannot exceed [10]. Therefore, for this purpose, one has to monitor the current flowing through motor. The main aim of soft starter is to minimize the starting current of motor and this measurement is done by using the device ACS712 current sensor circuit.

C. *Multi Tapped Transformer for AVR*

Voltage ranges from 180V to 260V for multi tapped transformer are shown in *Fig. 3*. There are total 9 taps for multi tapped transformer. Each tap has different voltage levels. When the input voltage is 220V then it appear on its 5 taping because transformer is having 1:1 ratio has difference of 10 volts on upper (230V-260V) and lower windings (180V-210V) from 5th tapping winding. Output voltages and turn ratios for fixed tapped transformer are shown in Table 1.

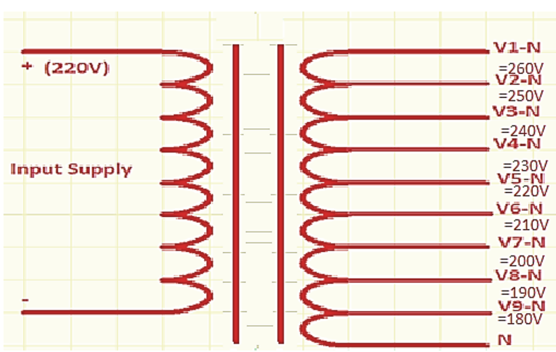

Fig. 3. Multi tapped transformer for AVR.

TABLE I
OUTPUT VOLTAGES AND TURN RATIOS FOR FIXED TAPPED TRANSFORMER

Sr. No.	Turn Ratio N_p/N_i; i=1,2,….,9	Voltage Ratio V_p/V_i; i=1,2,….,9
1	1.22	220/180
2	1.16	220/190
3	1.1	220/200
4	1.05	220/210
5	1.0	220/220
6	0.95	220/230
7	0.91	220/240
8	0.88	220/250
9	0.85	220/260

D. *Switches States for Different V_P*

Fig. 4 of multi tapped transformer shows that on primary side, input voltage supply range from 180-260V and on secondary side of the transformer, nine (9) voltage tapings are connected to load through switches (S1-S9). Switches states for different Vp (Input Voltages) are shown in Table II.

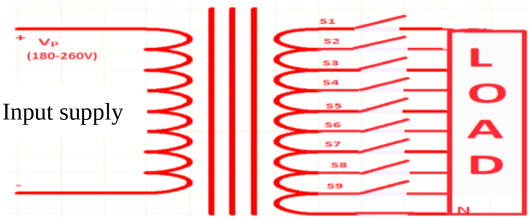

Fig. 4. Transformer connected with loads through switches.

TABLE II
SWITCHES STATES FOR DIFFERENT V_P

Sr. No.	Cases	Switches State	V_s (V)
1	If V_p=180	S_9=1; $S_1,S_2,S_3,S_4,S_5,S_6,S_7,S_8$=0	220
2	If V_p=180	S_8=1; $S_1,S_2,S_3,S_4,S_5,S_6,S_7,S_9$=0	220
3	If V_p=180	S_7=1; $S_1,S_2,S_3,S_4,S_5,S_6,S_8,S_9$=0	220
4	If V_p=180	S_6=1; $S_1,S_2,S_3,S_4,S_5,S_7,S_8,S_9$=0	220
5	If V_p=180	S_5=1; $S_1,S_2,S_3,S_4,S_6,S_7,S_8,S_9$=0	220
6	If V_p=180	S_4=1; $S_1,S_2,S_3,S_5,S_6,S_7,S_8,S_9$=0	220
7	If V_p=180	S_3=1; $S_1,S_2,S_4,S_5,S_6,S_7,S_8,S_9$=0	220
8	If V_p=180	S_2=1; $S_1,S_3,S_4,S_5,S_6,S_7,S_8,S_9$=0	220
9	If V_p=180	S_1=1; $S_2,S_3,S_4,S_5,S_6,S_7,S_8,S_9$=0	220

VI. SOFTWARE IMPLEMENTATION

A. *Power Supply for AVR*

In power supply circuit, supply voltages are stepped down to 12V using a step-down transformer and then filtered by low pass capacitors. The filtered voltages are then regulated using voltage regulator IC LM7805. It is a 3-Terminal IC which is used to regulate DC voltage from 25V to 5V. The maximum output current is provided by LM7805 is 1.5A. Limited internal current and thermal shutdown characteristics of these IC protect them from over-load [11]. Although used as fixed voltage regulators, these ICs can be utilized with external segments to get customizable output voltages and currents, and furthermore can be utilized as the power-pass component in voltage regulators. These regulated voltages are again filtered by capacitors as shown in *Fig. 5*. These voltages are finally used to provide power to the microcontroller and LCD.

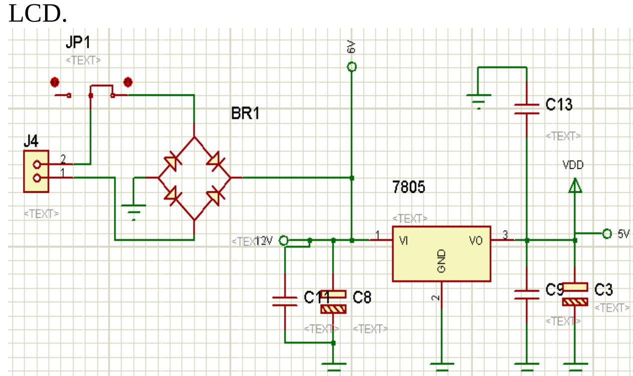

Fig. 5. Power supply circuit for AVR.

B. Power Stage for AVR

Microcontroller reads the line voltage as shown in *Fig. 6.* A pulse is given to PIC after zero crossing is detected, Whenever the line voltages vary, after obtaining this zero-cross pulse, PIC will determine the delay for sending the gate triggering pulse for TRIAC according to output of terminal voltage of the regulator. There are different windings of an isolation transformer with a difference of 10V from 180V-260V. If voltages are less than 220V then upper windings (step-up windings of T/F) are selected and similarly when voltages are greater than 220V lower windings (step-down windings of T/F) are selected. If voltages are within the range (220V) then 1:1 winding is selected.

VII. Results And Discussion

In TRIAC based automatic voltage stabilizer, the input voltage varies from 190V to 250V. This shows that the TRIAC maintains a constant voltage output at 220V, and it will be triggered if input voltage range is in between 190V and 250. In the experiments presented herein, the input voltage variation is achieved manually by the use of variable autotransformer called a Variac, where regulation is determined using the output voltage fluctuations [2].

The designing requirement is to stabilize automatically a large range (190V- 250V) of variation of input voltage at a normal prescribed level output voltage with a great precision. It is clear that, from above design and discussion. The comparison results of with and without proposed system are shown in Table-III, IV and V. It can be seen that the proposed TRIAC based automatic voltage stabilizer performs better than other existing systems. The proposed system is maintaining proper wide range of input variation, which provides protection against the high and low voltages that is crucial for the sophisticated electrical and electronic equipment [3].

This system is tested after designing for some typical AC input voltage supply. The regulated output voltage reaches to desired level which is explained in three forthcoming cases.

A. CASE 1 (Vp = 235V with different load conditions)

In case 1, the line voltages increase from the rated value to is 235V (over voltage condition) and load is varied from 0-360W. The proposed TRIAC based automatic voltage stabilizer regulate the output voltage. The regulated output voltage across the load and the voltage regulation for each load with and without improvement is shown in Table III.

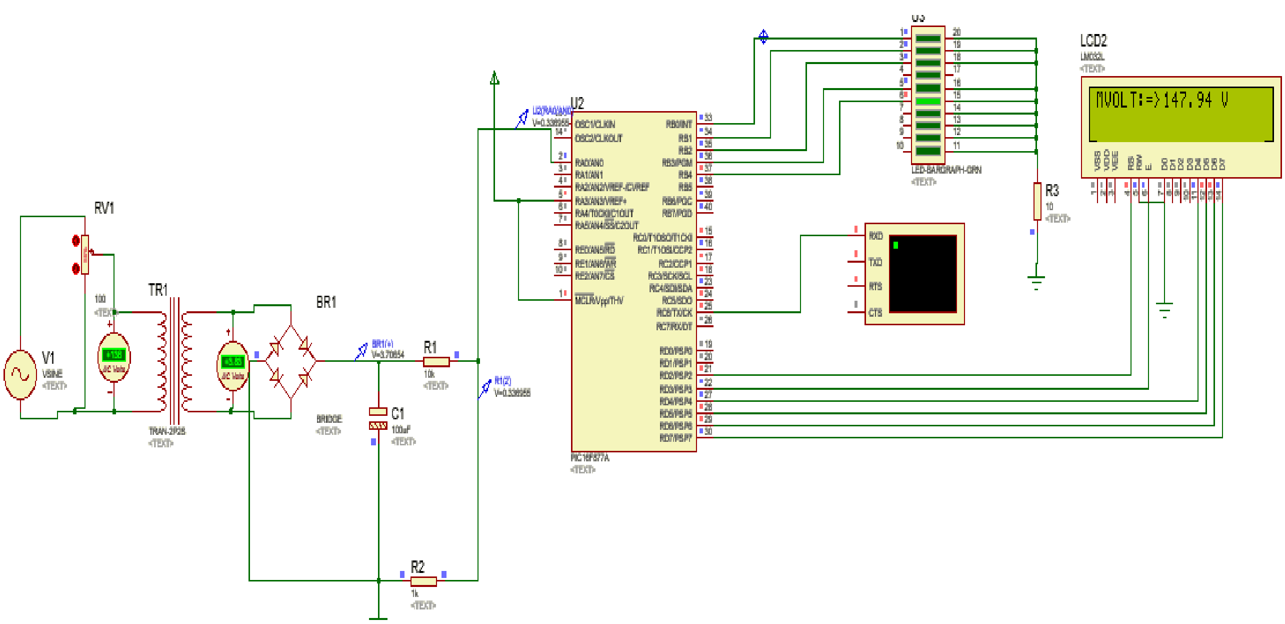

Fig. 6. Power stage circuit for AVR.

Table III
Voltage Regulation When V_p = 235v With Different Load Conditions

Sr. No.	Load (W)	V_p	V_s (Without Voltage Regulation)	V_s (With Voltage Regulation)	%Voltage regulation without improvement	%Voltage regulation with improvement
1	0	235	235	221	0	0
2	60	235	230	222	2.18	0.45
3	100	235	227	222	3.52	0.45
4	160	235	221	222	6.33	0.45
5	200	235	217	221	8.30	0
6	260	235	212	220	10.85	-0.45
7	300	235	205	221	14.64	0
8	360	235	200	219	17.5	-0.90

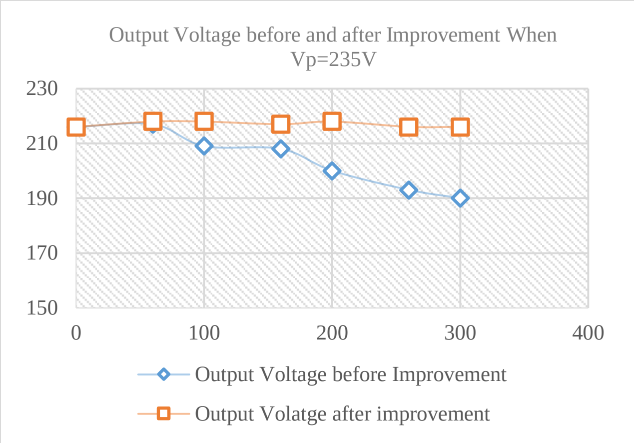

Fig. 7. Comparison of output voltages before and after improvement.

The graph shown in Fig. 7 describes the comparison of output voltages before and after improvement for load variations. Black line shows output voltages drops as load increases while red line shows that output voltages after regulation are in range (215V-225V) which result in stabilized output voltage under load changing conditions.

B. Case 2 (V_p = 220V with different Load Conditions)

In case 2, the supply voltage is 220V and load is varied from 0-360W. The proposed TRIAC based automatic voltage stabilizer stabilizes the output voltage. The regulated output voltage across the load and voltage regulation for each load with and without improvement is shown in Table IV.

The graph shown in *Fig. 8* describes the comparison of output voltages before and after improvement as load varies. Black line shows output voltages drops as load increases while red line shows that output voltages are in range (215V-225V) which provides stabilized output under load changing conditions.

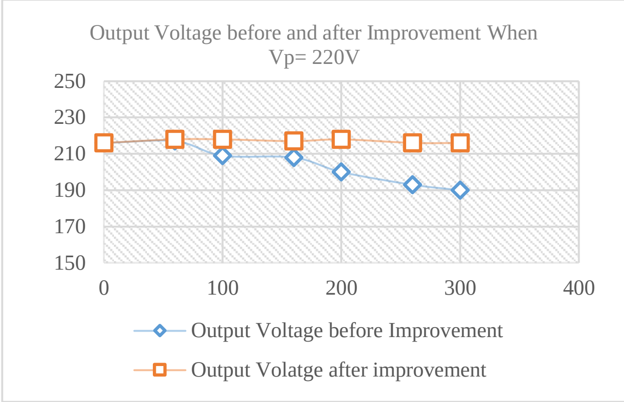

Fig. 8. Comparison of output voltages before and after improvement.

C. Case 3 (V_p = 210V with different Load Conditions)

In case 3, the line voltages decreases from the rated value to 210V (low voltage condition) and load is varied from 0-360W. The proposed TRIAC based automatic voltage stabilizer stabilizes the output voltage. The regulated output voltage across the load and the voltage regulation for each load with and without improvement is shown in Table V. The graph shown in *Fig. 9* describes the comparison of output voltages before and after improvement as load varies. Black line shows output voltages drops as load increases while red line shows that output voltages are in range 215V-225V providing stabilized output under load changing conditions. In this paper, TRIACs are utilized as switching device with number of transformer taps. Each tap is controlled by a suitable number of TRIACs. PIC microcontroller is utilized for controlling the circuit, which takes input signals and gives an appropriate output as per the directions stacked into the controller. The problem of slow transient response with high sparking of relay in conventional voltage stabilizer is successfully reduced using TRIAC based automatic voltage stabilizer.

TABLE IV
VOLTAGE REGULATION WHEN VP = 220V WITH DIFFERENT LOAD CONDITIONS

Sr. No.	Load (W)	V_p(V)	V_s(V) (Without Voltage Regulation)	V_s(V) (With Voltage Regulation)	%Voltage regulation without improvement	%Voltage regulation with improvement
1	0	220	219	220	0	0
2	60	220	216	219	1.39	0.45
3	100	220	211	220	3.80	0
4	160	220	210	219	4.29	0.45
5	200	220	204	220	7.35	0
6	260	220	202	219	8.42	0.45
7	300	220	196	217	11.73	1.38
8	360	220	194	215	12.89	2.36

TABLE V
VOLTAGE REGULATION WHEN V_P = 210V WITH DIFFERENT LOAD CONDITIONS

Sr. No.	Load (W)	V_p(V)	V_s(V) (Without Voltage Regulation)	V_s(V) (With Voltage Regulation)	%Voltage regulation without improvement	%Voltage regulation with improvement
1	0	210	216	216	0	0
2	60	210	217	218	-0.45	-0.91
3	100	210	209	218	3.25	-0.91
4	160	210	208	217	3.85	-0.45
5	200	210	200	218	7.41	-0.91
6	260	210	193	216	11.92	0
7	300	210	190	216	13.69	0.91

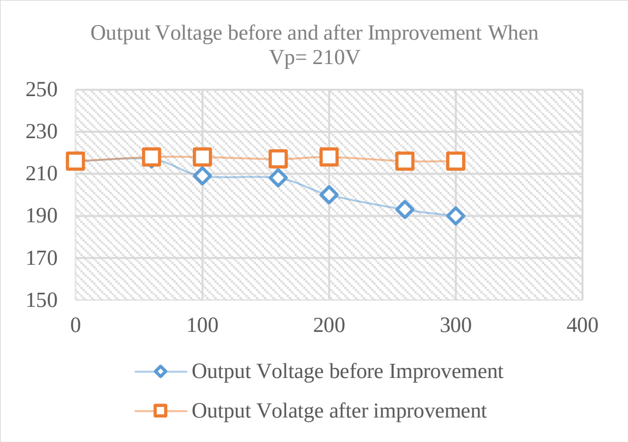

Fig. 9. Comparison of output voltages before and after improvement.

VIII. Conclusion

This paper presents the hardware implementation of PIC controlled TRIAC based automatic voltage stabilizer that utilized tap changing transformer for obtaining nominal AC voltage. Stabilizer is tested under different load conditions. It give satisfactory performance. It also provides over voltage protection, under voltage protection, overload protection and short circuit protection.

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Muddasar Ali has obtained BE Electrical Engineering from Air University, Islamabad in 2015 and MS Electrical Engineering from University of Engineering and Technology, Taxila in 2017. Currently, he is working as a Lecturer in Department of Electrical Engineering, University of Wah, Wah Engineering College, Pakistan. His research interest includes Power System Analysis, Power system Stability and controls. He is currently doing research on application of Artificial Intelligence Techniques in Power Systems.

Naveed Anwar has obtained BSc Electrical Engineering from Wah Engineering College, Wah Cantt in 2016. Currently, he is working as Lab Engineer in Department of Electrical Engineering, University of Wah, Wah Engineering College, Pakistan. He is currently pursuing MS Electrical Engineering from Wah Engineering College, Wah Cantt, Pakistan. His research interest includes Power System Analysis, Power system Stability and controls, Power Quality and Optimization Technique.

Syeda Tahreem Zahra has obtained BSc and MSc in Electrical Engineering from University of Engineering and Technology, Taxila in 2015 and 2017 respectively. Currently, she is doing PhD Electrical Engineering from HITEC University Taxila. Her research interest include power system analysis, High Voltage Engineering and optimization in power system.

Aqeel hayat has obtained BSc Electrical Engineering from Wah Engineering College, University of Wah, Wah Cantt, Pakistan in 2018. His research interest includes Power System Stability and Control.

Shahrukh Zaffar has obtained BSc Electrical Engineering from Wah Engineering College, Wah Cantt, Pakistan in 2018. Currently he is doing MS Electrical Engineering from Rome, Italy. His research interest includes Power System Stability and Control.

Shahid Iqbal has obtained BSc Electrical Engineering from Wah Engineering College, University of Wah, Wah Cantt, Pakistan in 2018. He is currently doing MS Electrical Engineering from COMSAT University, Islamabad. His research interest include Power System Stability and Control.