Analysis of conventional phase angle control fan regulators

[1]Sneha Waghare, [2]Akshay Deshmukh,
[1]Student , [2]Professor
[1]Department of Electrical Engineeering,
[1]G. H. Raisoni College of Engineering, Nagpur, India

Abstract: This paper presents the analysis of phase angle controlled type fan regulators. Nowadays phase angle control fan regulators are widely used. The drawback of this type of fan regulators is it gives very low power factor at low speed of fan motors. Therefore analysis of conventional phase angle control fan regulators has done in this proposed work with two types of fans. Conventional fan regulators consist of TRIAC whose switching depends upon firing angle. To study the causes of poor power factor at low speed experimental hardware results have been taken in this work for capacitor start and capacitor run induction motor and split phase induction motor.

IndexTerms - causes of poor power factor; displacement factor; distortion factor; Phase angle control; Single phase induction motor.

I. INTRODUCTION

Nowadays people using phase angle controlled regulator which consist of TRIAC as a controllable switch. TRIAC is a current controlled bidirectional switch which is used in regulators for symmetrical switching in both half cycles. The advantages of phase angle control regulators over other conventional regulators are its low volume and low cost. In these regulators speed control of fan is done by firing angle control. But the drawback of phase angle control regulator is it gives poor power factor at lower speeds. To find the causes of poor power factor proposed work is done in which regulator is tested on two types of fans. Some regulators consist of snubber circuit across TRIAC for protection, to find the effect of snubber circuit we have taken hardware results of regulators which consist of snubber circuit.

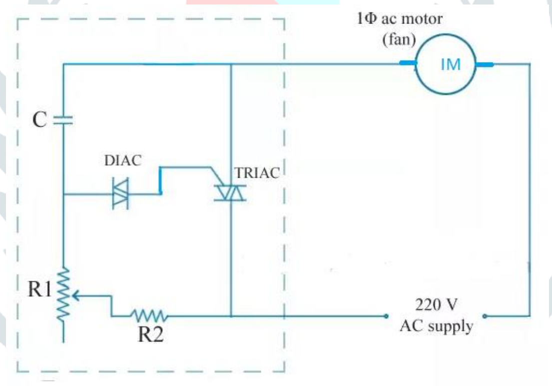

Fig.1 Phase angle controlled regulator

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II. ANALYSIS

RMS value of output voltage across induction motor is given by

$V_{0rms} = V_S/(\pi)^{1/2}*[\pi-\alpha+(\sin 2\alpha)/2]^{1/2}$ ---------------------------(1)

$V_{0avg} = 2V_m \cos(\alpha)/\pi$ -------------------------------------(2)

Where, V_s= RMS value of the AC source voltage

V_{0rms}= RMS value of the output voltage

α = firing angle

V_m = Peak value of the AC source voltage

Mechanical power of fan motor $P_m=T_L*\omega$-----------(3)

T_L proportional to N^2 therefore, P_m Proportional to N^3

Electrical power of motor = $V_sI_s\cos\phi$-----------------(4)

As $\cos\phi=\cos\alpha$

I_s is proportional to $P_m/(V_s\cos\alpha)$

I_s is proportional to $N^3/(V_s\cos\alpha)$

Power loss in induction motor is proportional to $I_s^2R_s$

Where, I_s source current, R_s is stator winding of motor

So we can conclude that if the power factor is low, source current increase therefore $I_s^2R_s$ is also increases.

$pf=(I_s/I_0)*\cos\alpha$---(5)

Where, I_0 is RMS load current, I_s/I_0 is distortion factor and cosα is displacement factor.

For any distorted waveform distortion factor is less than unity while for sinusoidal waveform distortion factor is unity.

From the above equations we can conclude that the power factor is depends on distortion factor and displacement factor.

With snubber circuit

$V_s=L(di/dt)+R_sI_s+(V_c)$-----------------------------(6)

$V_{0rms}=Vs-L(di/dt)$-----------------------------------(7) Where, L is load inductance

III. METHODOLOGY

In this proposed work conventional phase angle controlled regulator is tested on ceiling fan and exhaust fan to evaluate hardware results and comparison of performance of single phase induction motor on phase angle controlled regulators with and without snubber circuit.

[A] Phase angle control regulator without snubber circuit on Ceiling fan

For motors of small ratings we do not use snubber circuit as there is rate of change of voltage is less, results for phase angle control regulator without snubber circuit at different firing angles for small ratings of single phase induction motors are as follows.

Here, Blue waveform shows source voltage (Vs)

Yellow waveform shows voltage across load (V0)

V0= 200 volts/division and Time T = 5 millisecond/division

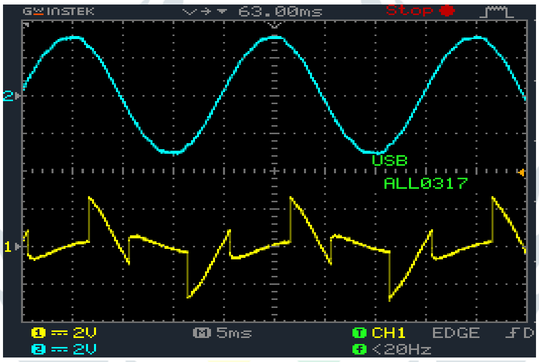

Fig. 2 At firing angle α = 135 degree

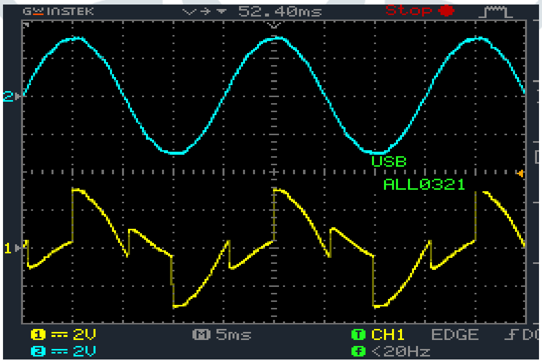

Fig. 3 At firing angle α = 90 degree

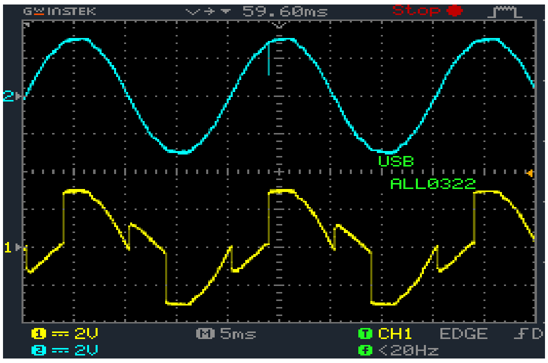

Fig.4 At firing angle α = 60 degree

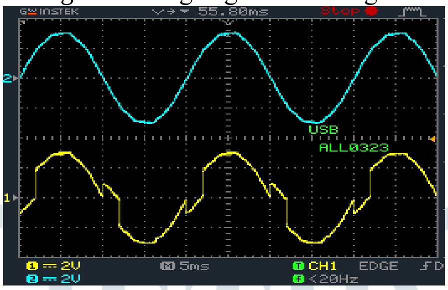

Fig.5 At firing angle α = 30 degree

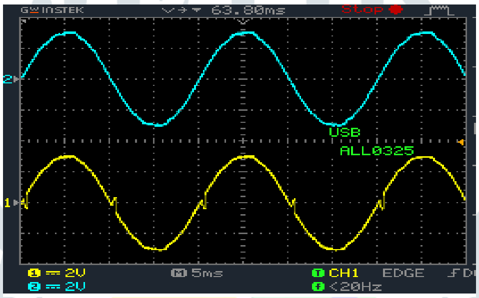

Fig.6 At firing angle α near to zero

[B] Phase angle control regulator with snubber circuit with ceiling fan

For large ratings of fan motors snubber circuits are used across TRIAC for dv/dt and di/dt protection. Here only for analysis we have taken results on low rating of motor. RC circuit is connected in series in which resistance is use to discharge the capacitor and inductor is use to limit rate of change of current. Following results are taken out on ceiling fan for detail study.

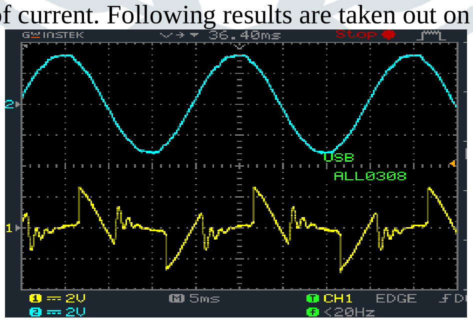

Fig.7 At firing angle α = 135 degree

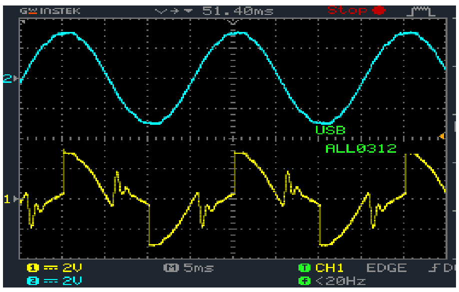

Fig.8 At firing angle α = 90 degree

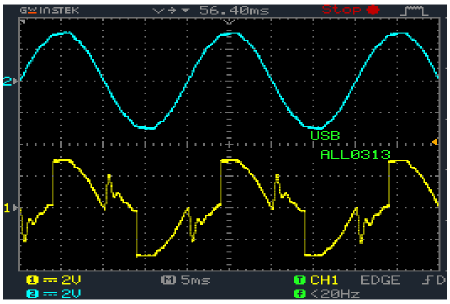

Fig.9 At firing angle α = 60 degree

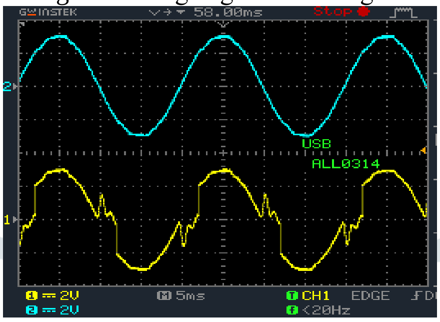

Fig.10 At firing angle α = 45 degree

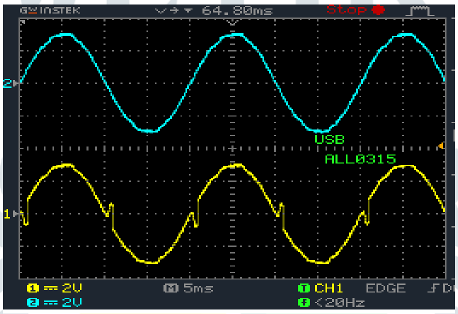

Fig.11 At firing angle α near to zero degree

From the above results we observe that regulators which consist of snubber circuit cause transients in output voltage because snubber circuit tries to limit the rate of change of voltage.

[C] Phase angle control regulator without snubber circuit with exhaust fan

Here performance of phase angle control regulator is studied on split phase induction motor as it does not contain capacitor in starting or running of motor so resonance effect does not observed.

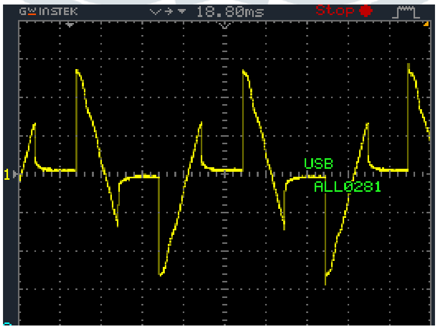

Fig.12 At firing angle α = 150 degrees

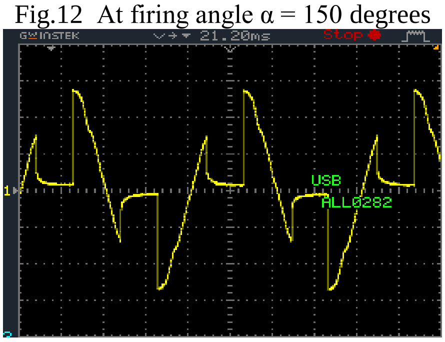

Fig. 13 At firing angle α = 135 degrees

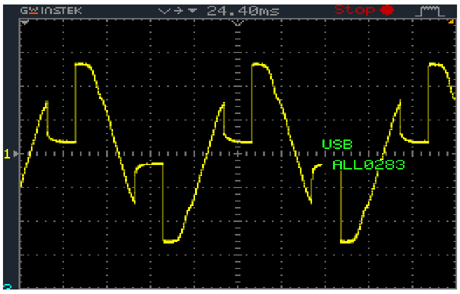

Fig. 14 At firing angle α = 90 degrees

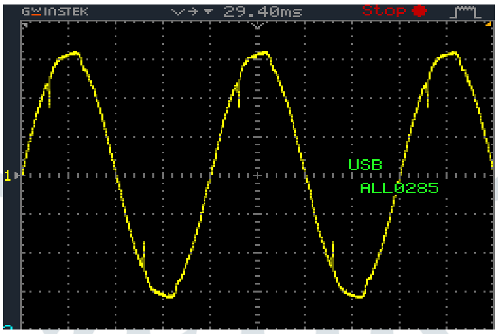

Fig.15 At firing angle α = 0 degrees

From the above results we observe that during off time of TRIAC due to reverse recovery time and recovery current power trapped so that it cannot freed and voltage that appears across load is diminishing in nature. Therefore during turn off TRIAC current does not falls down to zero immediately but it continues in negative direction and returns to a zero and turns off naturally during decaying nature. Similarly in negative half cycle also we observe the same operation. Whereas at firing angle near to zero we observe that the output voltage is nearly equal to the source voltage

[D] Phase angle control regulator with snubber circuit with exhaust fan

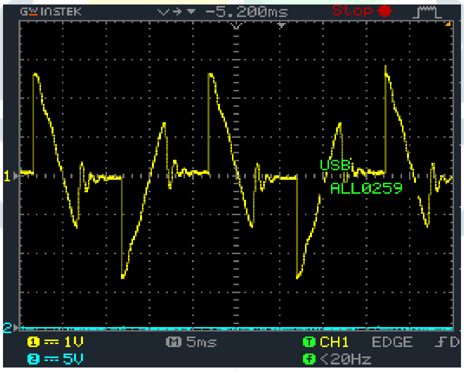

Fig.16 At firing angle α = 135 degrees

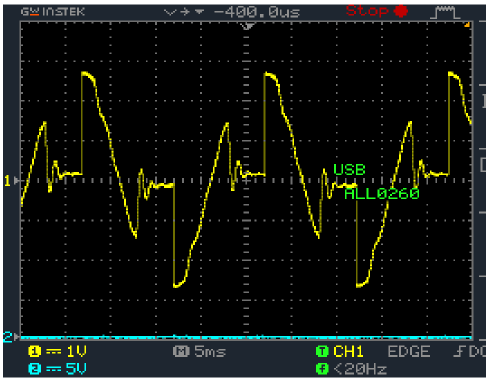

Fig.17 At firing angle α = 90 degrees

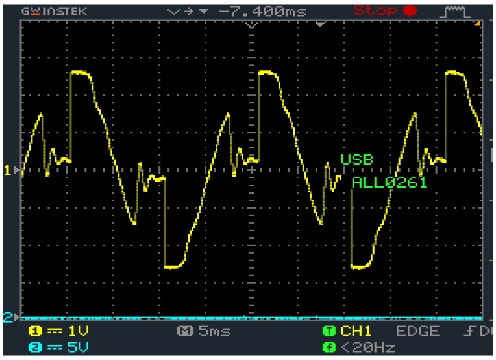

Fig.18 At firing angle α = 60 degrees

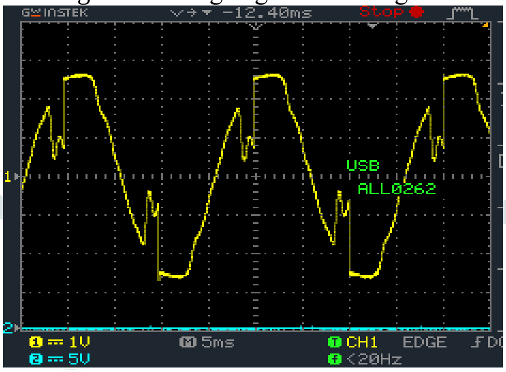

Fig.19 At firing angle α = 45 degrees

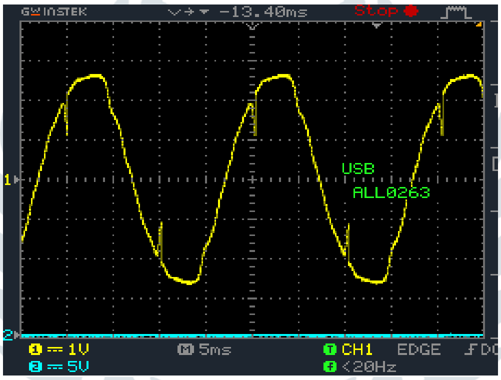

Fig.20 At firing angle nearly degree

From the above results we observe that during off time of TRIAC due to reverse recovery time and recovery current snubber circuit causes transients as it tries to limit rate of change of voltage and current.

IV. OBSERVATION

Table 1 Results on ceiling fan without snubber circuit

Sr. No.	Voltage (Volts)	Speed (RPM)	Power factor
1	90	83	0.452
2	130	129	0.639
3	160	205	0.732
4	185	252	0.871
5	230	374	0.993

Table 2 Results on ceiling fan with snubber circuit

Sr. No.	Voltage (Volts)	Speed (RPM)	Power factor
1	90	83	0.351
2	130	129	0.578
3	160	205	0.692
4	185	252	0.789
5	230	374	0.993

From table 1 and 2 we observe that power factor decreases because of snubber circuit. Also the power factor is very poor at low speed and high power factor at rated speed i.e. at firing angle near to zero thus it shows that increase in phase angle displacement reduces power factor.

Table 3 Results on exhaust fan without snubber circuit

Sr. No.	Voltage (Volts)	Speed (RPM)	Power factor
1	90	83	0.434
2	130	110	0.531
3	160	150	0.638
4	185	180	0.893
5	230	213	0.601

Table 4 Results on exhaust fan with snubber circuit

Sr. No.	Voltage (Volts)	Speed (RPM)	Power factor
1	90	83	0.334
2	130	110	0.639
3	160	150	0.732
4	185	180	0.871
5	230	213	0.601

Similarly, from table 3 and 4 we observe that power factor decreases because of snubber circuit. Also the power factor is very poor at low speed. While at rated speed i.e. at firing angle near to zero we observe the original power factor of split phase induction motor and power factor depends on firing angle and displacement factor.

V.GRAPHICAL RESULTS

(A) For ceiling fan

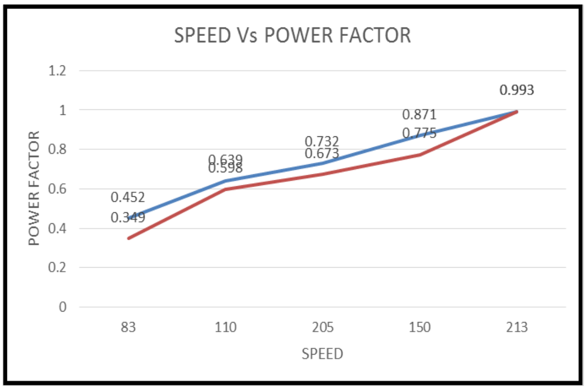

Fig. 21 Speed (RPM) Vs power factor

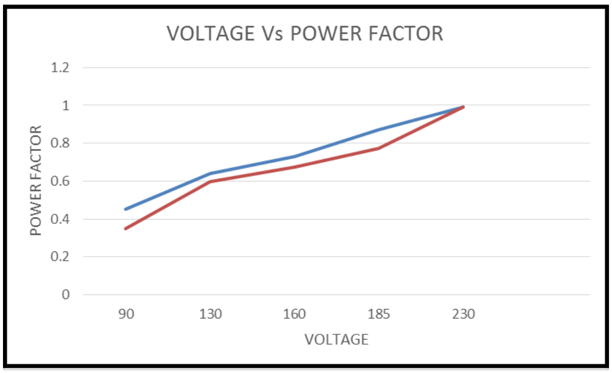

Fig.22 Voltage (Volts) Vs power factor

(B)For exhaust Fan

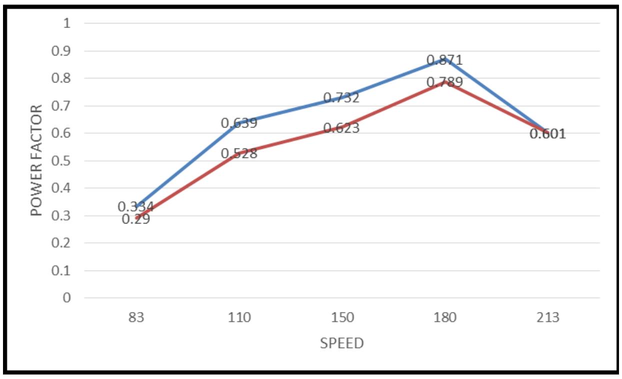

Fig 23 Speed (RPM) Vs power factor

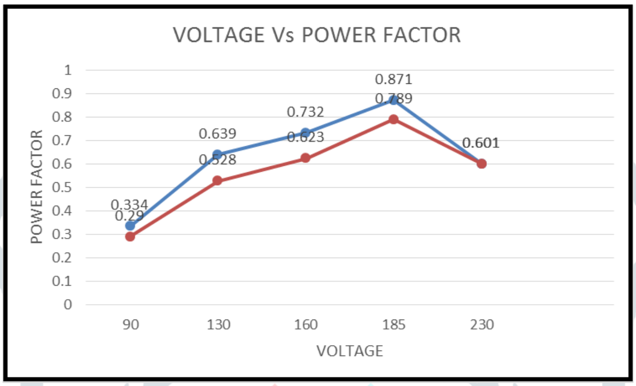

Fig. 24 Voltage (Volts) Vs power factor

From the above graphs we observe that power factor is lower when we use snubber circuit across TRIAC because distortion factor increases. Power factor in ceiling fan is more as compare to exhaust fan because of running capacitance of motor.

VI. CONCLUSION

Analysis of Phase angle control fan regulator is done in this paper with help of performance of two types of single phase induction motors. In this work we came to know that the power factor of motors depend on the firing angle of TRIAC. As we can see the displacement factor and distortion factor is not unity power factor is poor at lower speeds.

VII. REFERENCES

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