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DEVELOPMENT OF VAR/p.f. REGULATOR FOR BRUSHLESS AC GENERATOR TO BE PARALLELED WITH GRID

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Abstract: *The objective of project is to facilitate parallel operation of AC generators to grid at constant power factor or constant VAR mode to minimize line losses and optimal power. When different loads connected to the grid whose power factor is varies from 0.8 to 0.95 lag. The power demand from the grid depends on number of loads connected. The load pattern on the grid varies according to the number of loads connected.*

Keywords: *AVR, Automatic Power Factor Controller, Brushless A.C Generator, Grid. Automatic VAR/p.f Regulator*

I INTRODUCTION

The use of VAR/p.f. regulators has their origins in industrial applications of synchronous generators in which the synchronous machine is typically tied to a grid. In many of industrial applications, the machine voltage is expected to follow any variations in the utility-fed system voltage, in which case machine voltage regulation may not be as desired. Hence, VAR/p.f. regulators are used in conjunction with automatic voltage regulator for unattended paralleling current control on rotor while power fed to grid. During periods of peak system load, many areas are prone to voltage stability problems, in which case voltage on the heavily loaded system can slowly decay and collapse, unless proper reactive power support is provided. Also, analysis of events leading to recent power blackouts in the western United States has shown that the system problems were at least partially related to the lack of reactive power support from a number of generators on the system [1]. In such situations, it is important that all available generating stations will provide the correction of excitation level according to the desired VAR or p.f. in VAR/p.f. regulator and hence rotor is fully protected while the generator is fed power to grid. Hence, paralleling is unattended after generator is tied to grid.

II PRELIMINARY

When a synchronous generator is operating in parallel with a stiff bus, reactive current of generator is bound to vary, since bus voltage is uncontrolled. Hence, any voltage variation on grid results in variation of VAR supplied to bus in such situation. Hence, changes in VAR supplied to bus warrants suitable control. To achieve this, it is required to add a VAR/p.f. regulator device to the existing Automatic voltage regulator. Also, the VAR/p.f. introduced thereon is to have options to operate either in constant VAR or constant p.f. mode. In this context, the objective of the present project work is to develop a VAR/p.f. regulator, so as to achieve stable parallel operation for brushless AC Generator with Grid system.

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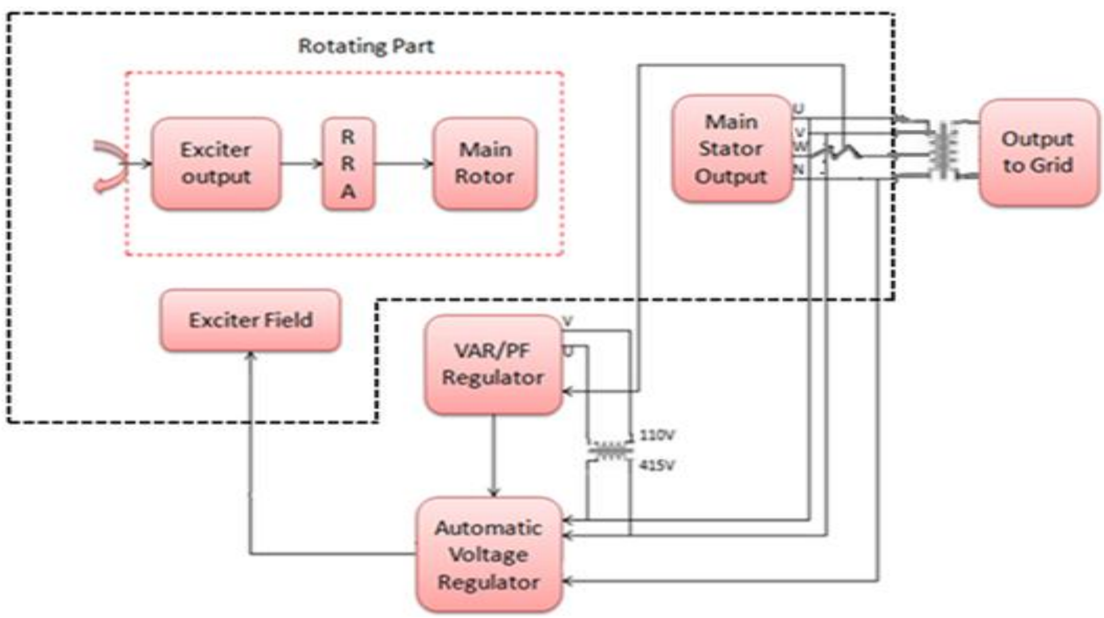

Fig.1: Block diagram of overall system.

III SCHEMATIC OF VAR/P.F. REGULATOR

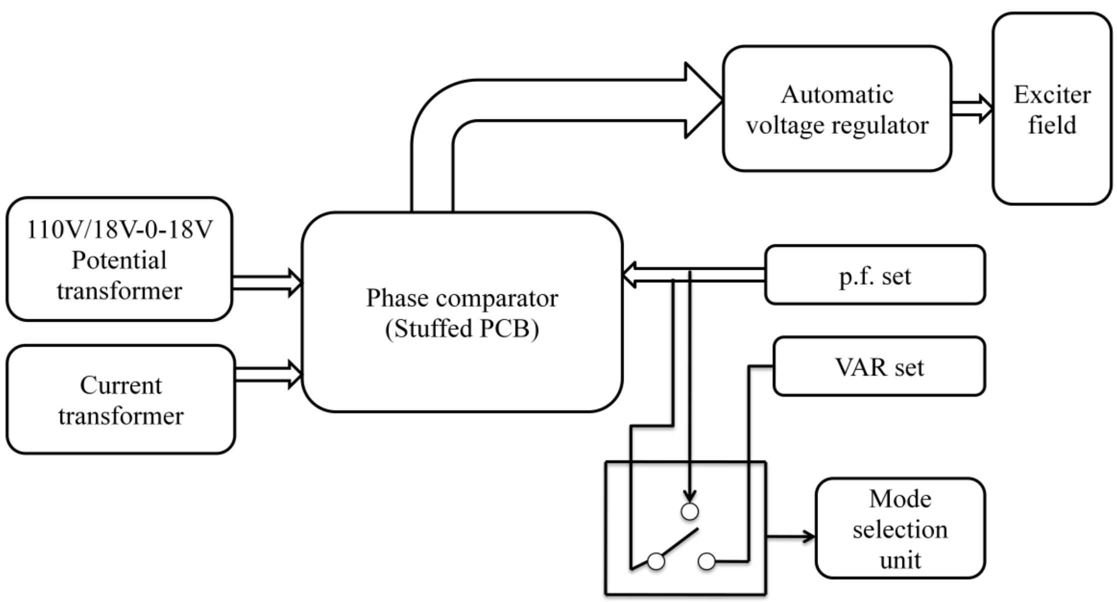

Fig. 2: Block diagram of VAR/p.f. regulator scheme.

Block schematic of VAR/p.f. regulator is shown in Fig. 2. The system consists of potential transformer, current transformer, phase comparator and mode selection (p.f. set or VAR set) unit. The stuffed printed circuit board (PCB) of VAR/p.f. regulator is known as phase comparator. The potential transformer of 110V/18V-0-18V is used, because the developed VAR/p.f. regulator device is designed to operate at 18V. Potential transformer is center tapped the voltage 110V to 18V-0-18V and provides it as an input to the phase comparator. 1A current transformer is used (standard CT rating is selected as 1A and provides it as an input to the phase comparator). In phase comparator of VAR/p.f. regulator, the phase angle between current and voltage is compared with respect to the desired power factor. The correction is applied between -5V to +5V with respect to the input to automatic voltage regulator at the external control input point of the regulator, till desired power factor

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is attained. The output signal of VAR/p.f. regulator is sensed by an automatic voltage regulator. The external control input of AVR starts correcting the excitation of the generator feeding power to grid till the desired power factor is attained. VAR/p.f. regulator is the built-in feature to act based on mode selection (p.f. set or VAR set). In case of constant VAR mode, power factor is governed to maintain the constant VAR. In case of constant p.f. mode, control of VAR is governed to maintain the desired power factor. VAR/p.f. regulator device is switched only when generator is paralleled to grid. To ensure this, provision is made to interlock VAR/p.f. regulator with grid circuit breaker.

Circuit diagram of VAR/p.f. regulator

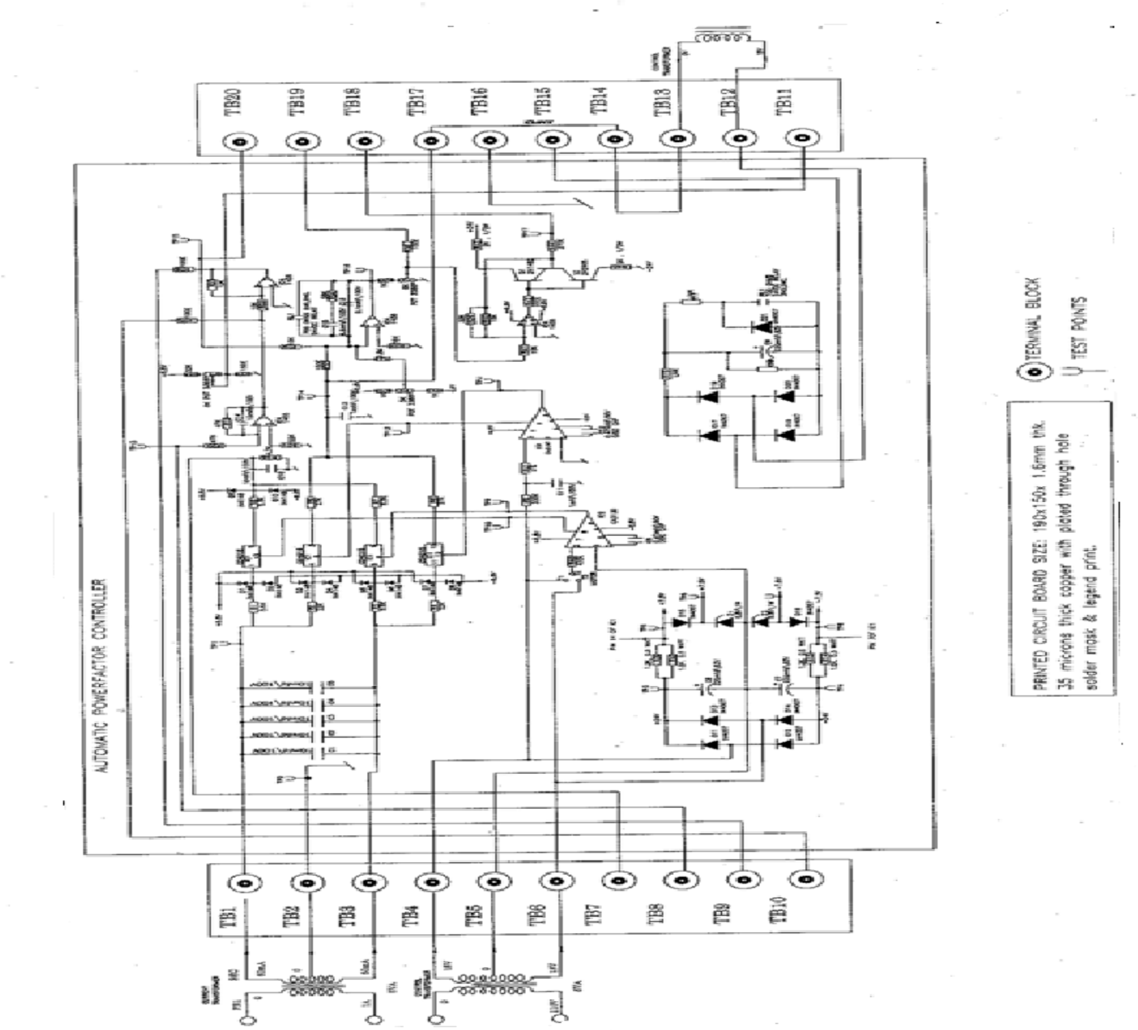

Fig.3.Circuit diagram of VAR/p.f. regulator.

Connection diagram of VAR/p.f. regulator

The connection diagram of VAR/p.f. regulator unit developed is shown in Fig. 4. Primary of potential transformer 110V/18V-0-18V is connected to terminal 1 and terminal 2 of VAR/p.f. regulator unit. Secondary of potential transformer is split into two sections. One of the secondary section of potential transformer is provided with center tap arrangement so as to provide 18V-0-18V. 18V terminal, center terminal of 0V and -18V terminal of potential transformer secondary are connected to terminal 4, terminal 5 and terminal 6 respectively of VAR/p.f. regulator PCB. Second section of potential transformer secondary providing 18V is connected to terminal 12 and terminal 13 of PCB terminals of VAR/p.f. regulator.

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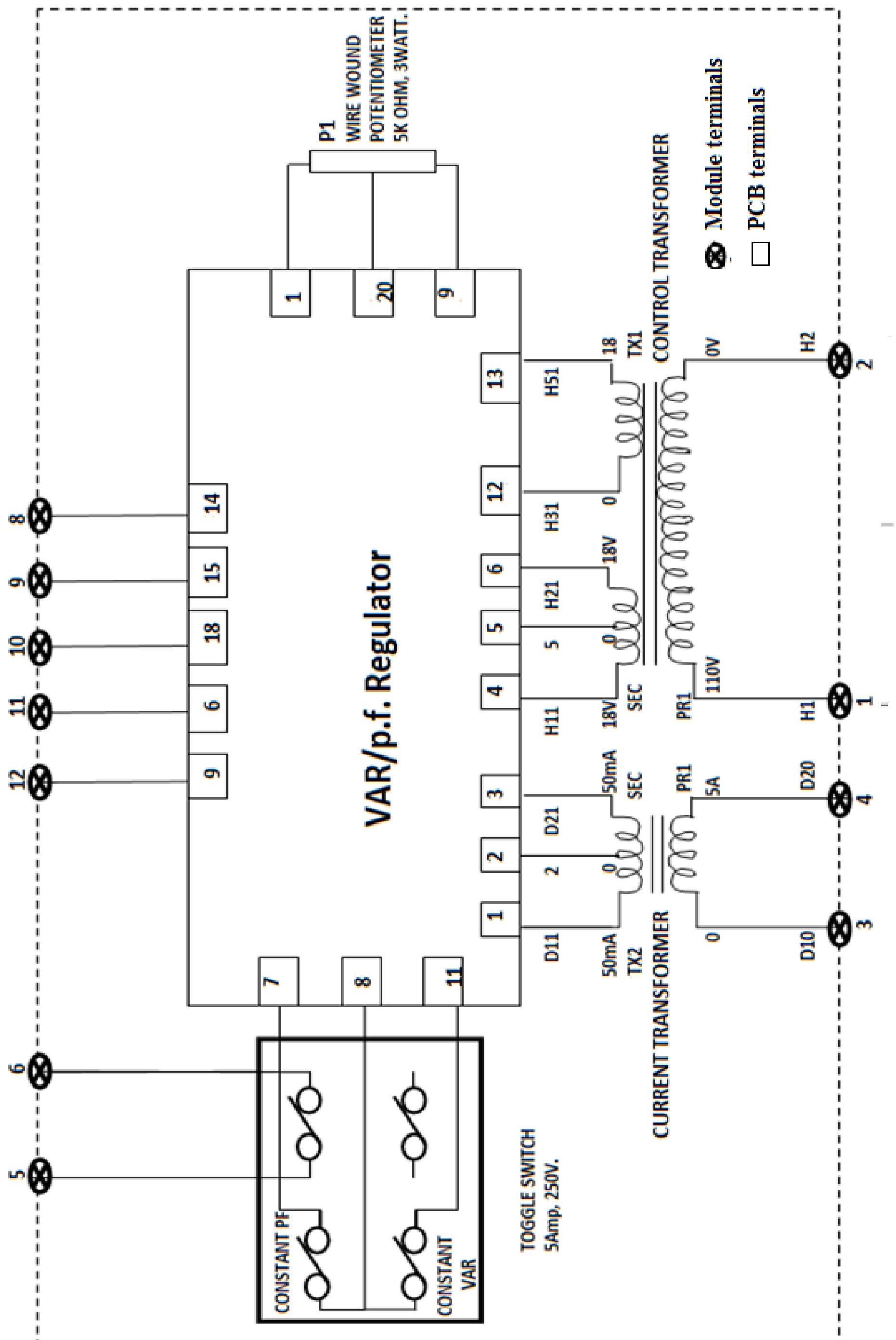

Fig: 4.Connection diagram of VAR/p.f. regulator.

Primary terminals of current transformer are connected to terminal 3 and terminal 4 of VAR/p.f. regulator unit. Secondary of current transformer is center tapped to realize 50mA-0-50mA connected to terminal 1, terminal 2 and terminal 3 respectively of VAR/p.f. regulator PCB terminals. Toggle switch of 5A, 250V is connected to terminal 5 and terminal 6 of VAR/p.f. regulator. Constant power factor and constant VAR switches are connected to terminal 7 and terminal 11 of PCB terminals of VAR/p.f. regulator unit. Wire wound potentiometer of 5kΩ, 3Watt is connected to terminal 1, terminal 20 and terminal 9 of VAR/p.f. regulator PCB.

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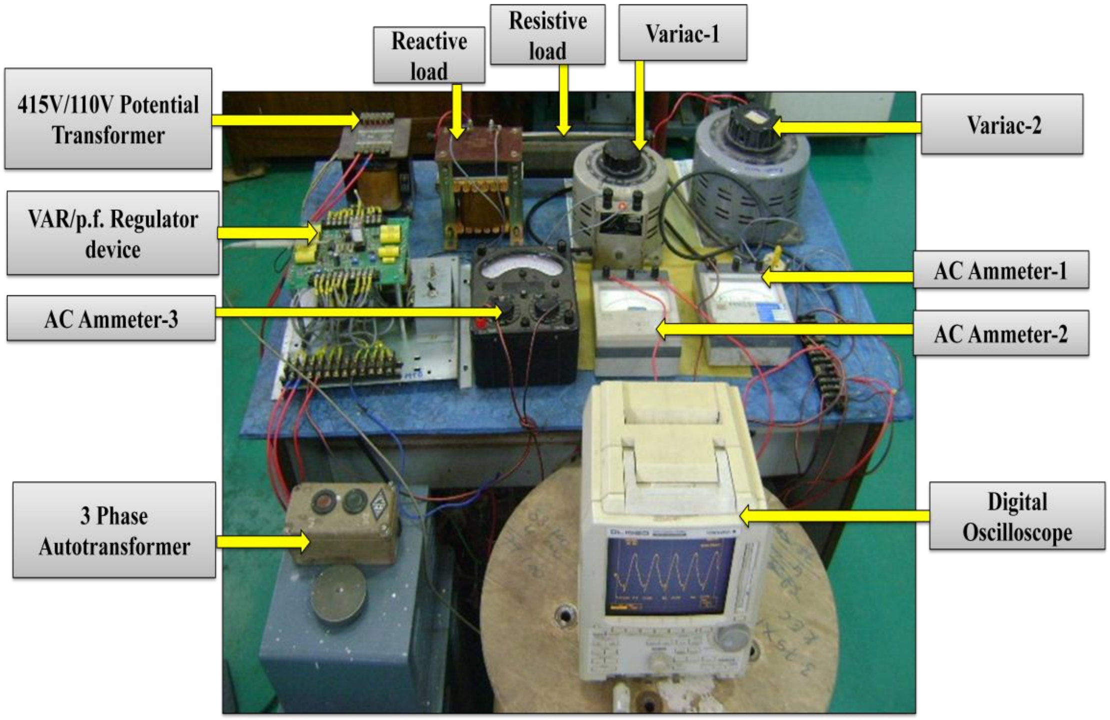
Experimental set up for power factor variation



Procedure for experiment conduction

In the present project work, static test and experiment for power factor variation are carried out. The purpose of conducting static test and power factor variation experiment are described in the next chapter. However, the conduction procedures of static test and experiment for power factor variation are stated in this section. Procedures adopted for conduction of tests are as follows:

Procedure for static test

- Connect secondary of current transformer of VAR/p.f. regulator to terminal block 1, terminal block 2 & terminal block 3 (refer Fig. 3.3) of stuffed PCB of VAR/p.f. regulator.
- Adjust reactive load and resistive load through variac 1 & variac 2, till 1A current is read in AC ammeter 3.
- Connect voltage source of 110V to potential transformer of VAR/p.f. regulator through 415V/110V potential transformer.
- Measure voltages at test points (TP) on stuffed PCB of VAR/p.f. regulator device.
- Connect 5kΩ VAR/p.f. pot to terminal block 10, terminal block 19 and terminal block 20 of VAR/p.f. regulator.
- Observe Cos Ø signal in digital oscilloscope at test point 13 on stuffed PCB of VAR/p.f. regulator.
- Observe Sin Ø signal in digital oscilloscope at test point 14 on stuffed PCB of VAR/p.f. regulator.
- Vary the VAR/p.f. set pot of VAR/p.f. regulator and observe the variation in output signal from positive to negative at output terminal blocks TB18 (terminal block 18) and TB19 (terminal block 19) of VAR/p.f. regulator.

Experiment conducted at 1Ampere current and 0.8 power factor

- Connections that are made to conduct static test are retained for power factor variation experiment. Initially, the value of I Cos Ø and I Sin Ø is set through variac 1 and variac 2 to be read on AC ammeter 1and AC ammeter 2. The vector sum of I Cos Ø and I Sin Ø currents is observed in AC ammeter-3.
- Adjust 5kΩ VAR/p.f. pot of VAR/p.f. regulator till the output voltage signal of VAR/p.f. regulator device at terminal block 18 and terminal block 19 is minimum (Ideally output signal level to be zero) against the current set in the previous step.

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- Vary 5kΩ VAR/p.f. pot position of VAR/p.f. regulator again. Observe the output voltage signal betweenTB18 and TB19 in digital oscilloscope to shifts from negative to positive (change in power factor setting).
- Vary (reduce) I Cos ∅ (AC ammeter 1) and keep I Sin ∅ (AC ammeter 2) constant, for a set current value (set anywhere between 25% to 100% of rated current - 1A). Observe the output signal change in digital oscilloscope at TB18 and TB19 (Observe output signal variation from positive to negative zone).
- Bring back AC ammeter 1(I Cos ∅) to initial position and vary (reduce) I Sin∅ against a particular set current value and observe output signal changes in digital oscilloscope with respect to terminals TB18 and TB19.

IV EXPERIMENTAL RESULTS

The output of zero crossing detector is square wave whose amplitude is around 7V peak as shown in Fig. 5. The generated output of zero crossing detector is fed to pin number 6 of IC1 (CD4016). The generated output at pin number 6 of IC1 (CD4016) provides input to I Cos ∅ component. Input of op-amp IC2 (CA3130) is phase shifted and the same phase shifted input is fed to zero crossing detector. The output generated from zero crossing detector is fed to pin number 12 of IC1 (CD4016), provides input to I Sin ∅ component.

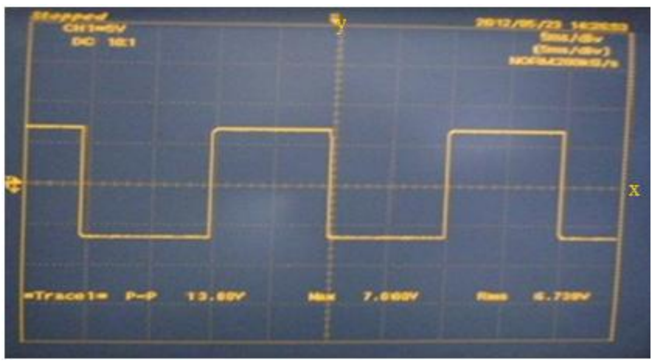

Fig. 5: Input signal to phase compensation circuit.

Output waveform in digital oscilloscope is observed at output terminal block1 (TB 1) of current built-in transformer of VAR/p.f. regulator device and is as shown in Fig. 6. Current from W phase derived from main current transformer 2705 of 1 ampere secondary is provided as input to built-in current transformer of VAR/p.f. regulator device.

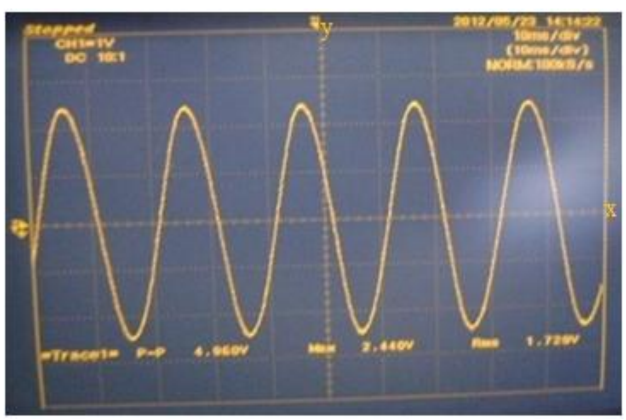

Fig. 6: Waveform observed at output terminal block 1(TB1) of current transformer.

Current at terminal block1 (TB1) derived as the output of secondary of auxiliary current transformer (current transformer of VAR/p.f. regulator device) is phase shifted by 180 degrees with respect to centre tap. The output of built-in current transformer of VAR/p.f. regulator device is filtered by means of non-polarized condensers to obtain the smooth waveform.

Waveform observed in digital oscilloscope at output terminal block 3 (TB 3) of current built-in transformer of VAR/p.f. regulator device is shown in Fig. 4.4.

Waveform observed in digital oscilloscope at input pin number 1 of IC1 (CD4016) is shown in Fig.7. The waveform obtained is the normal input to IC (CD4016).

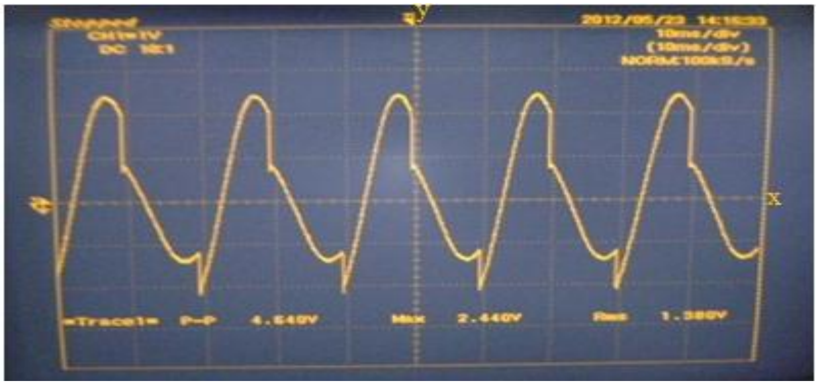

Fig.7: Waveform observed at input pin number1 of IC1 CD4016.

Waveform observed in digital oscilloscope at test point 14 is shown in Fig.8. The sinusoidal voltage input to op-amp IC3 (CA3130) functioning as zero crossing detector is phase shifted. The strobe output of op-amp IC3 (CA3130) from pin number 8 will provide an input to quad bilateral switch (pin number 5 of IC1). The output at pin number 3 of IC1(CD4016) due to input at pin number 5 and pin number 4 of IC1(CD4016) is proportional to current and voltage.

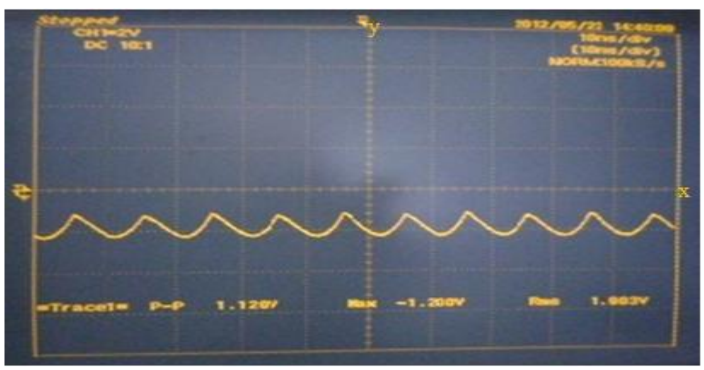

Fig.8: Output proportional to I Sin Ø component of current transformer input.

The output derived at pin number 10 of IC1(CD4016) due to input at pin number 11 and pin number 12 of quad bilateral switch (IC1 CD4016) is proportional to phase shifted current input and zero crossing detector output. The summation of output at pin number 3 and pin number 10 of IC1 (CD4016) is the voltage proportional to I Sin Ø component.

V CONCLUSIONS

In the present, the VAR/p.f. regulator has been tested successfully and obtained results are as expected at 1A current and 0.8 power factor. Important conclusions that are drawn out from the tests carried out in the present work are presented in this section. Measured voltages at different test points and the waveforms observed at various strategic points of the unit give way to the following conclusions:

- The signal strengths getting generated as input to various devices on stuffed PCB of VAR/p.f. regulator device are found to be satisfying the design requirement.

- Waveforms in digital oscilloscope are observed at terminal block 1 (TB1), terminal block 3(TB3), pin number 1 and pin number 8 of IC1 (CD4016), test point 13 (TP13) and test point 14 (TP14) are found to be complying with the design requirement.
- Current to voltage converter (metalized polyester capacitor) in VAR/p.f. regulator circuit is found to be effective for various current inputs (10% to 100% rated current) at desired power factor.
- The VAR/p.f. regulator device developed is found to be sensitive from 10% to 100% rated current (1A).
- The output voltage signal of VAR/p.f. regulator device is observed in digital oscilloscope. This signal used as input to AVR unit, from terminal blocks TB18 and TB19 of VAR/p.f. regulator, is found to be effective during change in desired power factor.
- Change of power factor or VAR by means of varying VAR/p.f. set pot of VAR/p.f. regulator device is found to be effective to regulate the power factor.
- Output voltage signal of VAR/p.f. regulator device in digital oscilloscope is observed to vary from -5V to +5V or vice-versa. This can effectively result is superior control in regulating the p.f. as desired.

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