Design of Low Cost Embedded Power Plant Relay Testing Unit

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Abstract:
This Paper presents a method of designing an Automated Simple PWM based three phase sinusoidal signal generating unit to test the Voltage monitoring, frequency monitoring and Synchronizing or synchronism-check relays. Knowledge of sinusoidal wave generation using PWM scheme and Knowledge of Micro chip Microcontroller Products is required. MATLAB software and MPLAB IDE 6.5 used to design the all system.

***Keywords**: PWM (pulse width Modulation Technique)*
CEB (Ceylon Electricity Board)

I. INTRODUCTION

This report aims at giving an idea of developing a Low cost embedded small power plant relay testing Unit with tested circuits.

Testing the performance of protective relays before they are installed and maintenance tests after they are installed are essential to ensure the proper operation of relays. In today's world, where demand is continuously increasing, the transmission capabilities of existing networks need to be increased too. This forces the relay engineer to examine the present and future relays in greater detail. The major challenge in testing is to simulate as closely as possible, the conditions under which the relay is going to operate. This means the electric power system, which is one of the most complex man-made networks need to be modeled. **These paper only concerns about the Grid connected embedded small power plants.**

II. ISLANDING DETECTION AND PROTECTION

Protection relays are used to detect abnormal electrical conditions in the grid which may indicate that an isolated condition has occurred. They may also indicate that the grid system is, for some other reason, outside operating conditions, and embedded generators should be disconnected. After a distribution line, to which an embedded generator is attached is disconnected from a grid sub station, there will be some disturbance in the electrical condition on the distribution line. This disturbance may take the form of,

1) Change in voltage or frequency
2) Single shift in the voltage vector
3) Change in reactive power flow.

Therefore, it is important factor to declare protection relays and recommended settings are to be used to detect an islanded situation are listed in the following sub sections. The settings of the relays should be agreed with the CEB and the setting shall not be changed without the express agreement of CEB.

It must be noted that the total tripping time given under each type of protection includes any integration or timing period of the protection relays as well as relay and circuit breaker operating times. Numbers of relays are listed below with their settings for the easy understandings about the protective relays.

III. PROTECTIVE RELAYS

A. over and Under Voltage

The voltage of each phase is monitored and any excursions outside preset limits on any one phase should cause the relay to operate.

Settings

Level for HV point of connection: ±10% of nominal 230V.

Level for LV point of connection: +10% to -14% of nominal 230V.

Total tripping time: shall be less than 0.5 second

Limits should not exceed or be less than the maximum and minimum statutory voltage by more than a few percent and should be based on declared nominal voltage. Total tripping time can be increased by agreement between CEB and the generating companies.

B. Over and Under Frequency

The frequency on a single phase is monitored and any excursions outside preset limits will cause the relay to operate.

Settings

Level: +4% to -6% (i.e. 52 Hz to 47 Hz)

Total tripping time: No requirement for a time delay.

Total tripping time shall be less than 0.5 second. It may be possible for the low frequency to be reduced to 46 Hz given the possibility of grid recovery from 47 Hz. This will need to be confirmed with CEB.

C. Rate of Change of Frequency

RoCoF relays operate by measuring the zero crossings of successive sliding cycles of the measured voltage, establishing the apparent rate of change of frequency and detecting when the applied setting is exceeded.

Settings

Limits: 2.5 Hz/second, specified to ensure there is minimum spurious tripping.

Total tripping time: No requirement for a time delay.

Total tripping time shall be less than 0.5 second.

D. Voltage Vector Shift

Vector shift relays operate by measuring half cycle voltage and detecting a step change exceeding an equivalent vector shift setting. It detects a voltage vector shift arising when there is a step change in the current through the generator internal impedance. Voltage vector shift is inherently a protection to disconnect a generator from disturbances and is susceptible to spurious tripping during faults because it detects voltage angle disturbance rather than the characteristic of the islanded condition.

Setting

Level: 6º in a half cycle can be de-sensitized up to 12º where spurious tripping is exceeded.

Total tripping time: No requirement for a time delay.

Total tripping time shall be less than 0.5 second.

E. Synchronizing Check Relay

A synchronous check relay must be used to inhibit the operation of the generator connection breaker. This relay will prevent connection of the generator to the grid when the two supplies are outside pre-set limits. This can be achieved using an electrical interlocks.

Settings

± 20 % of phase angle

Maximum difference in voltage of supplies of 7% of the same nominal voltage

Maximum slip frequency: 0.44%

Total tripping time: 0.5 to 2 seconds, on the operation of relay is commonly used to ensure the slip frequency is within limits.

Synchronous check relays may operate on a single or all three phases of the supplies. A single phase relay will not be able to check for phase rotation of the two supplies. If a single phase relay is used, then the phase rotation of the two supplies must be checked prior to first connection.

IV. ABNORMAL CONDITION WAVE FORM GENERATION

Relay testing system should be able generate the wave forms changing magnitude, frequency and phase angle. Also main issue is collecting data's about relay operation time and response of the relay.

PWM pulse generating unit is the heart of the design and Hardware model would be a Microcontrollers. The PWM pulses will be amplified by High voltage IGBT's. In order to generate three waves the hardware model would have six IGBT's and the PWM pulses turn on and off the IGBT's in appropriate order.

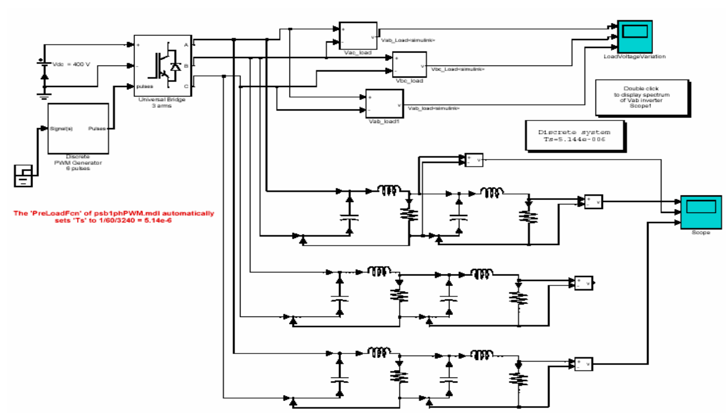

Fig.1 Matlab model for PWM based three phase wave form generation

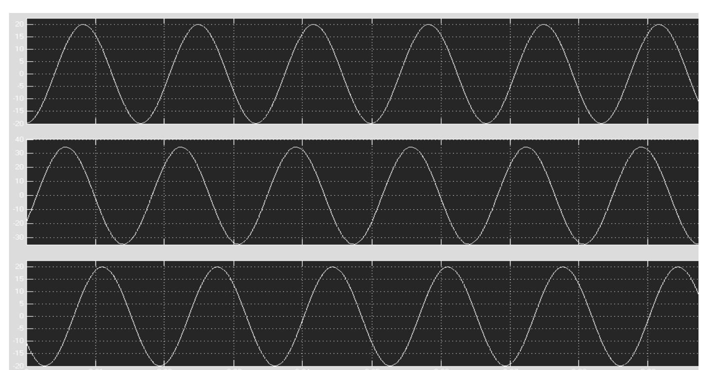

Fig.2 Wave out puts

a) Factors influences in the IGBT selection and Driver Circuit design.

1) IGBT voltage rating
2) IGBT short circuit withstand time
3) Thresh hold voltage of the Gate input

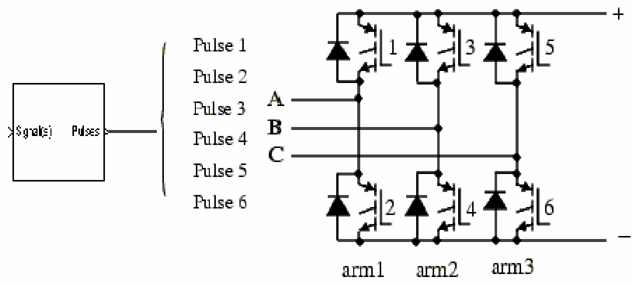

Fig.3 IGBT circuit

Six PWM pulses drive the IGBT's and actually Microcontroller generates three pulses and pulse2 is inverted pulse of pulse1.Pusle4 and pulse6 are inverted pulses of pulse3 and pulse5 respectively.

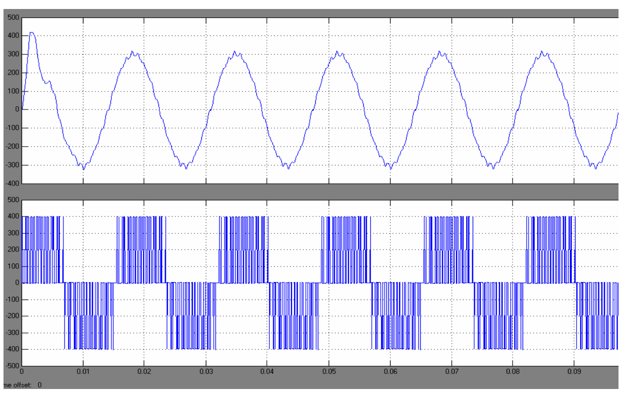

Fig.4 PWM pulse and low pass filtered sinusoidal output.

The duty cycle period of the PWM pulse will very with phase of the sinusoidal wave form. Magnitude of the wave depends on the average PWM duty cycle for given 1 cycle period of the wave form and frequency of output wave depends on the PWM period.

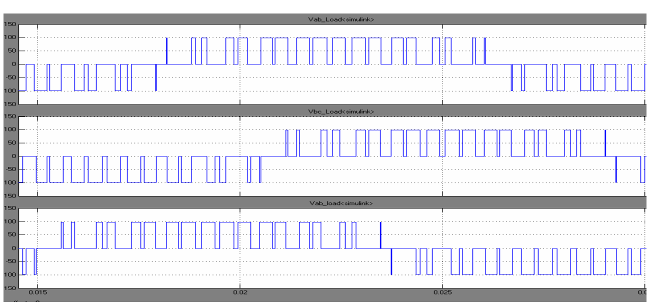

Fig.5 PWM pulse pattern of sinusoidal three phase output.

V. HARDWARE IMPLEMENTATION

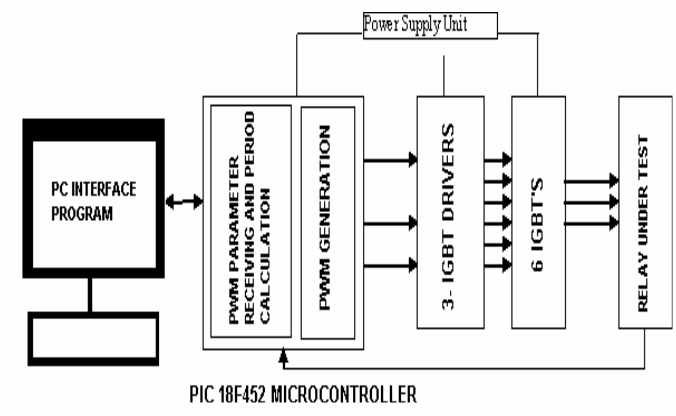

Fig6: Block Diagram of the Overall system

Personal computer is the interface (GUI) between user and the power electronic circuit. User enters the parameters of the test to this interface screens. Then these parameters are validated and send to the micro-controller via serial port. This information is used to generate the output waveforms to the Relay under Test (RUD).

User Inputs

1) Voltage (R-Y-B)
2) Frequency (Hz)
3) Phase angle (R-Y, Y-B)
4) Vector Shift
5) Voltage /frequency Ramp

Microcontroller is the unit which acquires the signal parameters sent by the user and generates appropriate PWM driving signal to the six-pack driver module.PIC18f452 microcontroller is used for this design. This microcontroller has special features such as direct serial port connectivity through MAX232 chip, PWM output capability, 4 timers, large program memory, data memory etc.

Microcontroller is the most important part and the most complex part of the design. It does two basic functions.

1) Data Transmission
2) PWM generation

Therefore it is clear that software program inside microcontroller has two modules, one for each function. The information sent by the user via parallel port is stored in a separate memory area using Data transmission module. This information is used to generate desired PWM output. During the relay operation, tripping time is measured using the feedback signals (Relay pick-up signal & Stop signal) from the relay. Once the test is finished, the test results are sent back to the PC using Data Transmission module again.

VI. IMPLEMENTATION OF SINUSODIAL PWM USING TABLE REFERENCE

This is a software implementation method of sinusoidal PWM and one of the easiest methods. In this method, sine wave is sampled at each 10 degree period so that 18 samples per half cycle (from 270 to 90 degrees) and calculates the duty cycle.

TABLE1
SINE TABLE REFERENCE FOR PWM GENERATION

	Sample (Degrees)	Point	Duty cycle
	270	270	
	280	260	
	290	250	
Offset-2 ↑ →	300	240	
	310	230	
	320	220	
	330	210	
	340	200	
	350	190	
Offset-1 ↓ →	360	180	
	010	170	
	020	160	
	....		......
	....		......
Offset-3 ↑ →	60	120	
	070	110	
	080	100	
	090	090	

The 3 pointers called offset-1, offset-2 and offset-3 are placed 0 - 120 - 240 apart. Each pointer is corresponding to one phase.

For a given frequency, time taken to move 10 degrees along the sine wave is calculated. Let's take this time as TIMER0_OV. Then each TIMER0_OV period, all the offsets are shift by one table entry in the direction indicated in arrows. When an offset meets an edge of the table, it reverses the direction of movement.

VII. CHANGING VOLTAGE, FREQUENCY AND PHASE SHIFT.

Duty cycle of the PWM pulses associate with the voltage. Therefore by multiplying all the table entry duty cycles from a scaling factor makes it possible to vary the output voltage. If the frequency is increased, it affects TIMER0_OV value to decrease and vice versa. Therefore, by varying the TIMER0_OV value, user can vary the frequency output. By varying the offset positions, user can change the phase angles.

PIC18f452 has two dedicated hardware modules to implement PWMs. Each module is called CCPx module (Capture/Compare/PWM) includes special registers, output pins to implement PWMs.Operation of CCP1 and CCP2 modules are identical to each other and involve following registers.

a) PWM Period setting

PWM period is set by PR2 register. The frequency of the PWM (i.e. the Carrier frequency) is the inverse of this period (1/period).

PWM period = [(PR2) + 1] *4 * Tosc* TMR2 prescale value . (1)

b) Duty Cycle Setting

The PWM Duty cycle is specified by writing to the CCPR1L and to the CCP1CON <4:5> bits. This gives 10-bits resolution for duty cycle setting.

PWM Duty Cycle = [CCPR1L: CCP1CON <4:5>] * Tosc * TMR2 prescale .(2)

As it is mentioned earlier, PIC18f452 has two hardware PWM output pins. The third one is implemented using software. I.e. Timer 2 and Timer 1 control the software PWM.

VII. CONCLUSION

This paper briefly carried the Modification of the three phase induction motor driver to a Relay Testing wave form generating Unit. This Unit can be further developed to do advanced functionalities of actual relay testing Unit's in the Market. The design should have some safety requirements on the high Voltage IGBT unit and there must be a optical isolation between the High voltage side and low voltage side. For further information refer the References given in the paper.

REFERENCES

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[2] Microchip AN889 application for VF Control of 3-Phase Induction Motors Using PIC16F7X7 Microcontrollers.

[3] Microchip PIC18FXX2 Data Sheet.

[4] International rectifiers IRG4BC20KD-S IGBT data sheet.

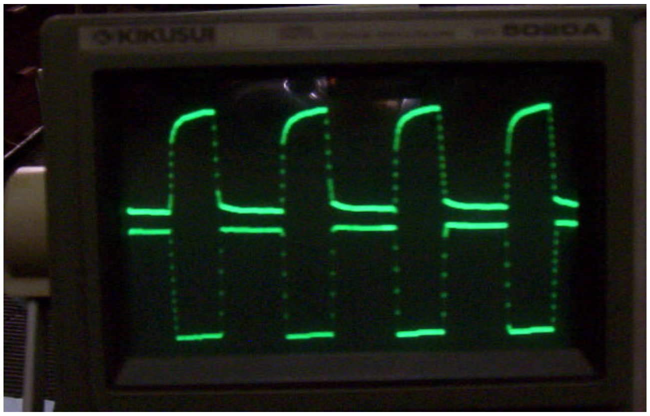

Fig.6 IGBT driving signals from IR2108 high speed IGBT/MOSFET driver

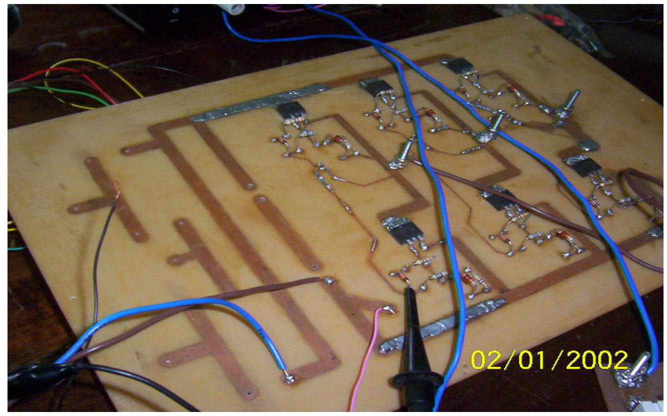

Fig.9 Six IGBT driver circuit

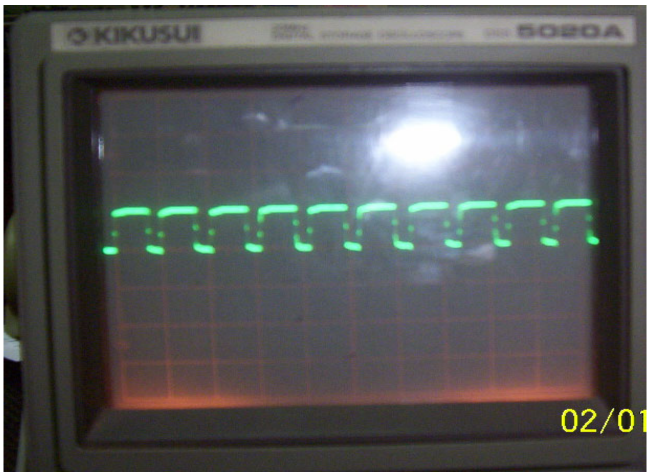

Fig.7 PWM pulses from the PIC18F452 Microcontroller

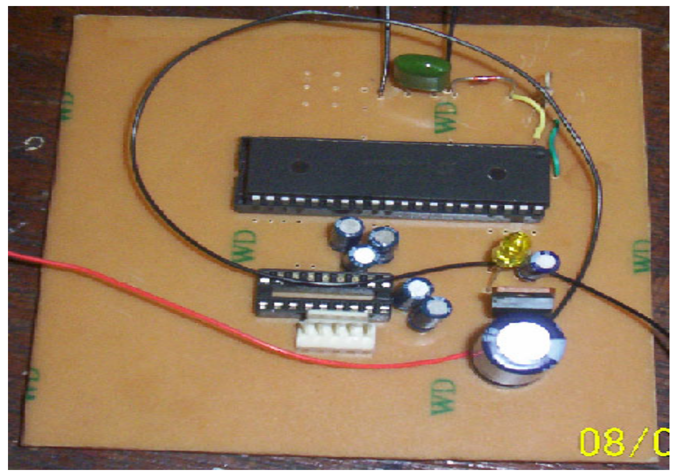

Fig.10 Microcontroller circuit Board

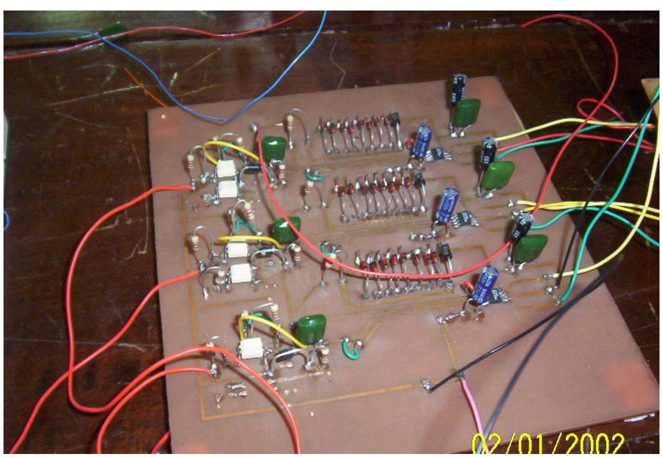

Fig.8 IR208 driver circuit Board