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Automatic Synchronization Unit for Parallel Operation of Two Alternators Using Cortex-M0

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Abstract:- A microcontroller based system is developed which verifies the conditions required for the synchronization of two alternators, viz.

- The terminal voltage of two machines must be equal.
- The frequency of two machines should be same.
- The phase sequences of two machines are bound to be same.
- The voltage phasors of both machines must be in phase
- Or within close vicinity of each other as far as the local circuit between the two machines is concerned.

The system checks for the fulfilment of these conditions. If all the conditions are verified then the system connects the two machines in parallel otherwise it prompts the user to take remedial steps that suffice the conditions.

I. INTRODUCTION

- We made the automated device, which makes two alternators automatically synchronized.
- This device continuously displays sufficient electrical parameters of two alternators.

Fig. 1: Two alternators which we have synchronized

II. BLOCK DIAGRAM

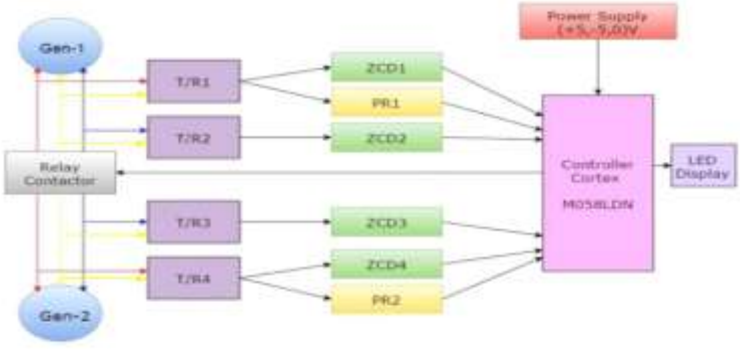


Fig. 2: Block Diagram

The figure shown beside represents the block diagram of the circuit. The line voltages from both the machines are stepped down by the use of 4 separate step-down transformers.

Now the inbuilt ADC requires a constant voltage during its conversion period. Hence the stepped down line voltage is then given to precision rectifier circuit, which converts the sinusoidally varying voltage into D.C. voltage which then goes to inbuilt ADC pin.

The microcontroller understands only the two levels i.e. either 0 or 1. In order to check the phase sequence & frequency it is required that the sinusoidal voltage is converted into a square wave which has only two levels either 0 or 1. For this purpose a Zero Crossing Detector (ZCD) circuit is used. The square wave output from ZCD is fed to one of the port pins of microcontroller. The circuit is duplicated for the second machine too.

The 7SEG LED display is installed as an output device which displays various from both the machines e, g. voltage frequency, phase sequence etc. looking at which user has to take some decisions.

A relay and contactor circuit is used to put the two machines in parallel. After all the necessary conditions of synchronization are fulfilled, the microcontroller sends a signal to relay, which drives the 3-Phase mechanical contactor to connect the machines in parallel.

III. HOW IT WORKS?

A. Measurement of Electrical Parameters

1) Voltage:

- Convert 230V (L-L) to 9V using transformer
- Convert 9V AC into DC using Precision rectifier
- Measure voltage level using inbuilt ADC in controller
- Multiply by M.F. and display it.

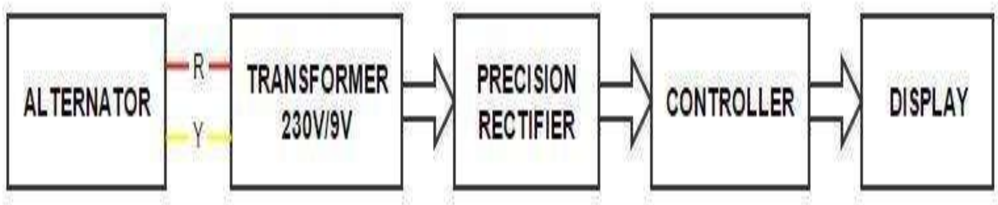


Fig. 3: Flowchart of voltage measurement

2) Frequency:

- Convert 230V (L-L) to 9V using transformer
- Convert 9V AC (sine wave) into square wave using Zero crossing detector
- Measure frequency with the output of ZCD using inbuilt timer of controller
- Multiply by M.F. and display it.

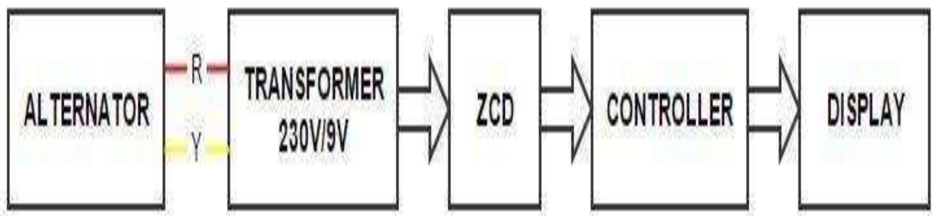


Fig. 4: Flowchart of frequency measurement

B. How both the alternators are synchronized?

The basic performance of the microcontroller is to measure and compare the voltage, the frequency and the phase sequence of both the machines. In addition to which the opposition of voltage in the local circuit is also checked. These operations are carried out as followed.

Conditions for synchronization

1) Phase sequence of two alternators must be same.
2) Line voltage of two alternators must be equal.
3) Frequency of two alternators must be nearly same.
4) Voltage phasors of both alternators should be in phase or within close vicinity of each other. To satisfy above conditions, some errors are acceptable.

1) Measurement & comparison of phase sequence: Here, the time elapsed between the instant R phase becomes low and the instant Y-phase goes low is measured For this purpose a timer is initiated and started as soon as it is found that a edge falling pulse is received at the pin P1.4 & P1.7. The procedure is repeated for the second machine too. Finally, after obtaining the counts for both the machines decision is taken by comparing the two counts. Taking the difference of counts carries this out. The difference thus obtained must be within predetermined limits. If it is found to be so, then it is confirmed that the phase sequence is correct or ideal and the next step is executed otherwise the supply is to be switched off and any two phases of either of the two machines are interchanged.

2) Measurement & comparison of voltage: The first condition to be checked is the voltage equality. Inbuilt ADC of controller is employed to convert the analog voltage into digital quantity. The phase voltages of both machines are given to separate precision rectifier circuits, the outputs of which are connected as input of ADC. By the use of proper handshake signals, the microcontroller receives the digitally converted voltage through one of its ports. The difference is then carried out of two digital values. This difference is compared with a predetermined limit. If it is found confined within this limit then the next condition is checked otherwise the measurement of voltage is carried out again and the above condition is verified till the difference suffice the condition. Varying the field excitation of machines can satisfy the condition.

3) Measurement and comparison of frequency: The frequency is measured by taking the count corresponding to 360°. For this purpose a timer is initiated as soon as a Edge falling pulse is received at pin P1.4 and incremented till P1.4 receives a falling edge. The count thus obtained is time of one cycle. This is time for one cycle. The inverse is then taken to obtain the frequency. This procedure is carried out for second machine also. Again the difference of the frequency counts from both the machines is compared with a predetermined value. This measurement & checking is done repeatedly till the difference is found to be within a permissible value. This difference can be brought within this limit by varying the speed of prime movers.

4) Check for voltage opposition in the local circuit: In addition to the above three conditions the essential final condition that has to be satisfied without fail is the local circuit phase opposition. This can be verified by measuring the time between the receptions of rising edge at pin P1.4 to the reception of falling edge at pin P1.0. A timer is incremented between the instants. The timer contents should be as small as possible to ensure safe synchronization. In other words the two voltage phasors must be in phase at the instant of switching to have minimum damage to machines and operator resulting due to sparking.

5) Relay and Contactor: An electromechanical contactor is employed to make the live connection between the two machines. The actuating coil of contactor can be fed from 230 volt mains or from any of the two alternators line to line. The circuit is made such that the current does not flow through the contactor coil until & unless the relay contactors are closed. So in order to close the contactor, the relay coil has to be energised. An NPN transistor is used as a switch to drive the relay coil, whose base is connected to controller via resistor.

IV. SCHEMATIC DIAGRAM

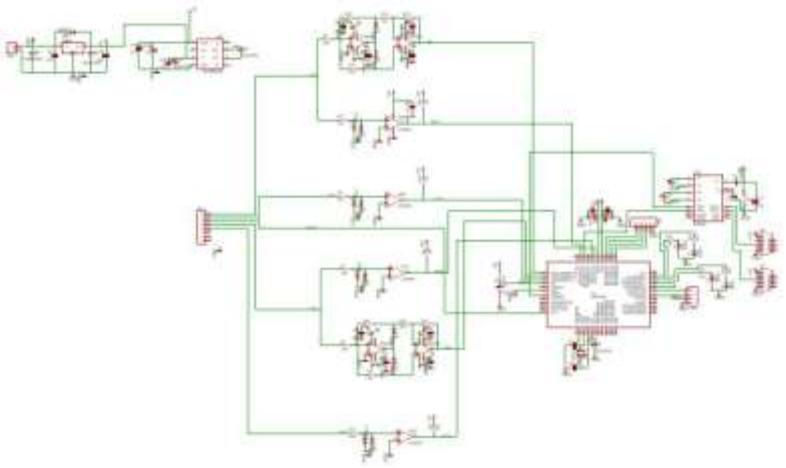


Fig. 5: Schematic Diagram

V. HARDWARE DESCRIPTION

A. D.C. Power Supply
components used:

- Voltage regulator chips – 7805, 7660.
- Diode – 1N4007
- Filter capacitors – 1000uF/35V, 104 , 10uF/25V

We had used 12V DC 2A adaptor to convert 230V AC to +12V DC. That 12V DC is converted to regulate +5V DC using 7805 IC. From this +5V, we are getting -5V using IC 7660.

This +5V we are giving to OP07 IC & LM-339 and the microcontroller. And -5V we are using for negative supply to IC OP07.

For the 7-Segment display, we are using +12V.

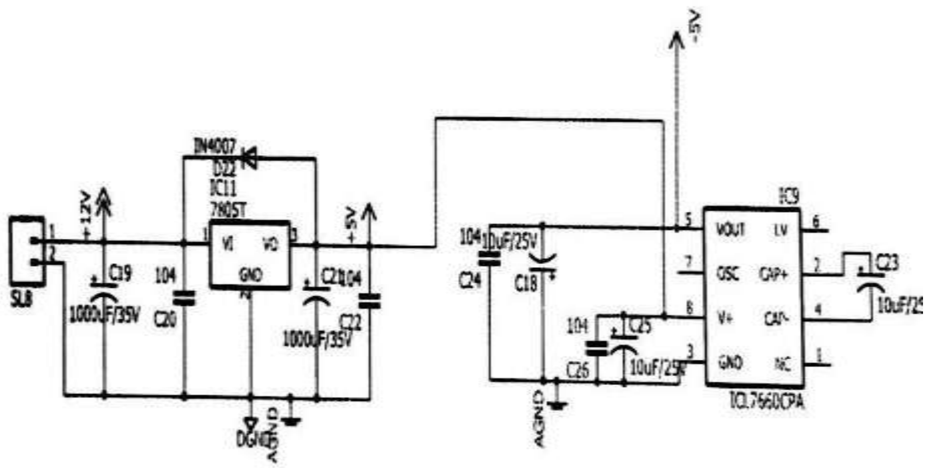


Fig. 6: D.C. Power supply

B. ***Precision Rectifier***

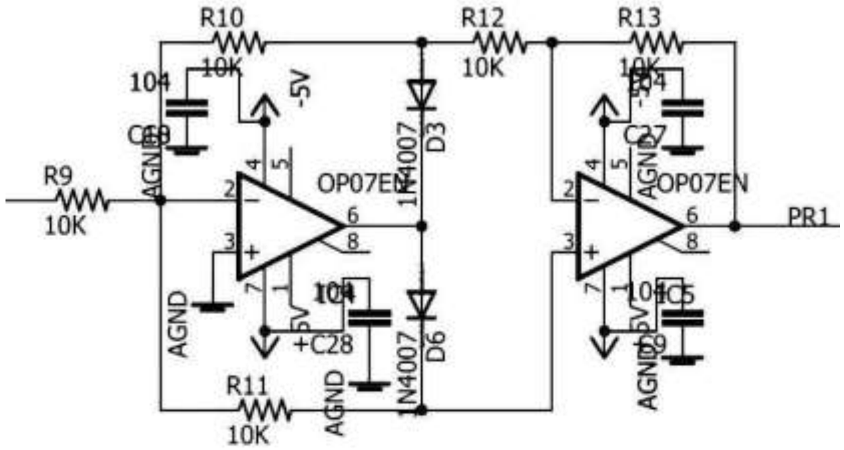


Fig. 7: Precision Rectifier

COMPONENTS USED:

- Diodes IN 4007
- Operational Amplifiers OP-07
- Capacitors 0.1uF
- Resistors 10k, 20k

Rectifier is a component of an electric circuit used to change alternating current to direct current Rectifiers are made in various forms which are all operating on the principle i.e. the current passes through them freely in one direction but only slightly or not at all in the opposite direction.

A low pass filter can be used to increase the rectifier's speed & reduce the ripple voltage. However a precision rectifier is used to reduce the content in the output because if there is ripple component in the D.C. output, the displayed digits on the microprocessor will flicker which us not desirable. Hence a precision rectifier is used.

In ordinary rectifiers i.e., half wave rectifier, a full wave rectifier or a bridge rectifier, the output will start from the diode switching on voltage i.e. 0.7 volts so there is considerable amount of ripple in the output. But a precision rectifier uses an op-amp so the output waveform start from a value obtained by dividing 0.7 volts by the open loop gain of the op- amp. And we know that the open loop gain of the op- amp is very high & hence the output waveform will start very to the zero giving approximately characteristics. So the ripple content is considerably in the precision rectifier.

C. ***Zero Crossing Detector***

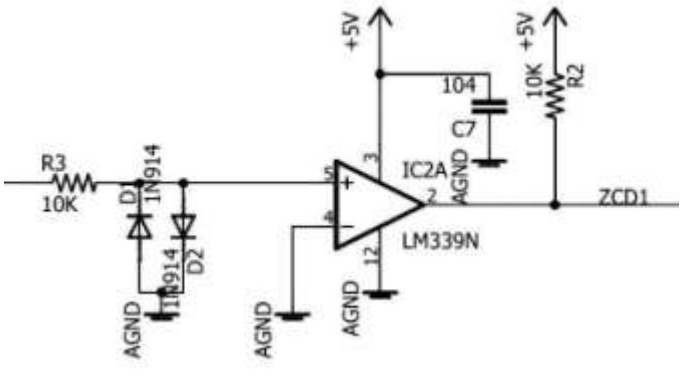


Fig. 8: Zero Crossing Detector

Components Used:

- Non-inverting OP-amps LM 339
- Diodes IN 914
- Resistors 10K
- Decoupling capacitors 104AEC

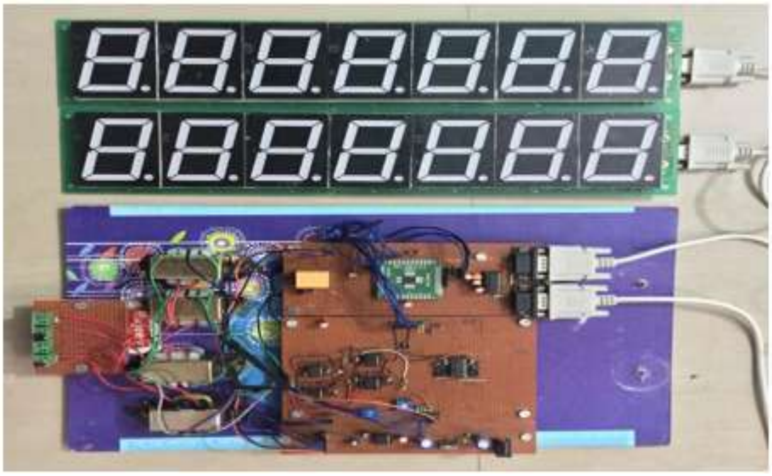
The online values of line voltages from both alternators are fed to the ZCD circuit.

The op-amp IC LM 339 has a limitation that it's input voltage should not go more negative than -0.3 volts, when minimum supply voltage is zero. So the germanium diodes are used instead of silicon diodes which provides a drop of not more than 0.3 volts when forward biased each diode conducts in respective half cycles of input sine wave. Thus, the sinusoidal waves chopped above 0.3 volts in both half cycles are fed to the op-amps, which convert them into square waves.

Thus, sinusoidally varying line voltages have been converted to the microcontroller compatible square wave signals. The resulting signals are then fed to the separate input port pins of microcontroller.

The resistors are provided to reduce the voltage levels. And the decoupling capacitors are connected as the surge suppressors. The reference voltages needed for the op-amps are provided from the voltage regulator circuit.

VI. PRACTICAL VIEW



VII. ALGORITHM

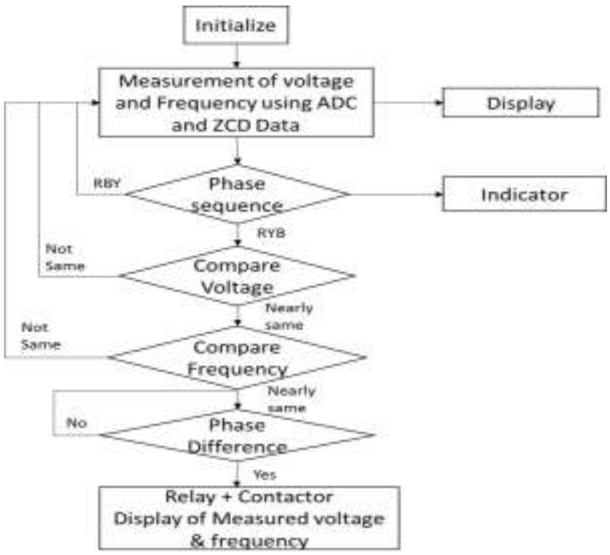


Fig. 9: Algorithm

VIII. CONCLUSION

We have developed a device in which Voltage and Frequency of two alternators are continuously displayed. And it also shows whether the phase sequence is correct or not. When all conditions of synchronization satisfy, two alternators are synchronized with the help of Contactor. Thus our device can use in power station to synchronize alternator with bus quickly.

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