Investigation of Performance of Automatic Synchronization of Alternator using PLC

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Abstract— Automatic synchronization of alternator with bus bar will share the load by synchronizing the Voltage and Frequency with the help of chopper circuit and Programming Logic Control (PLC) automatically. Further this system can be controlled through SCADA, GSM, Data Acquisition System and various automatic controllers to control the load and automatic generation control without much human interference which will minimize the human errors and the system will be made more reliable.

Keywords: PLC, Synchroscope, Alternator, Voltage, Frequency

I. INTRODUCTION

It is well known that electrical load on a power system or an industrial establishment, is never constant but it varies. To meet the requirement of variable load , economically and also for assuring continuity of supply the number of generating units connected to a system bus bar are varied suitably. The connection of an incoming alternator to system bus, i.e. synchronization requires fulfillment of the condition like the same phase sequence equality of voltages and frequency between the incoming machine and frequency between the incoming machine and bus bar. Automatic synchronization of alternator with bus bar will share the load by synchronizing the Voltage and Frequency with the help of chopper circuit and Programming Logic Control (PLC) automatically.

In this paper automatic starting of DC motor (working as prime mover) is done by using chopper circuit. Also automatic excitation voltage control of alternator and Automatic frequency control (maintain generated emf) is done by using chopper circuit and Programmable Logic Controller.

II. AUTOMATIC SYNCHRONIZATION

Synchronization by means of manually operated switching served well enough when the individual generators were relatively small, but with the growth of system capacity, it becomes necessary to use automatic devices to ensure the closing of the main switch of the incoming machine at the proper instant.

The scheme introduced here is for the complete automation of synchronization i.e. the adjustment of magnitude of voltage and frequency of incoming alternator is done automatically. When all the requirements of synchronization are satisfied, closing of the main switch of the incoming machine is done automatically.

When alternators are in parallel operation and the load increases all of a sudden, then alternators can share the current impact evenly and can bear larger impact than that on the single set, at the same time, two alternator sets in parallel operation can stabilize the voltage and the frequency.

The auto synchronizing has been developed to carry out the following tasks related to the synchronization such as

1) To check if the phase sequence of incoming machine is correct or otherwise, in case of wrong phase sequence, to terminate the further steps in the process and also to indicate corrective action.
2) To check if frequency of incoming machine is equal to that of bus bar and to adjust it to a value nearly equal to the bus bar frequency.
3) To check machine voltage is equal to that of bus bar and to adjust it to a value nearly equal to the bus bar voltage.
4) After ascertaining the fulfillment of the above condition, to give closing signal to the contactor so that the breaker will close the exact in phase instant .In addition, the auto synchronizing has been designed so that the alternator is started with in minimum voltage and minimum frequency conditions.

III. SYNCHROSCOPE:

In AC electrical power systems, a synchroscope is a device that indicates the degree to which two systems (generators or power networks) are synchronized with each other.

Synchroscopes are used in any power plant that connects to an outside power grid and also in isolated plants containing more than one generator. Each generator must be synchronized with the others before being connected to the plant bus. If line voltages are unequal when they are connected, a heavy current will flow as each line will attempt to equalize the other, causing damage in the process.

Fig. 1: Synchroscope

The armature of the synchroscope will align itself so that the axes of windings are R and F is inclined at an angle equal to phase displacement between V and V'. If there any difference between the frequencies of V and V' a pointer attached to the armature shaft will rotate at slip speed, and the direction of its rotation will indicate whether the incoming machine is running above or below synchronism. At synchronism, the pointer will remain stationary, but it must be brought to the particular position which indicates zero phase displacement between V and V' before the main switch of the incoming generator is closed.

A. Block diagram of PLC based Alternator Synchronization

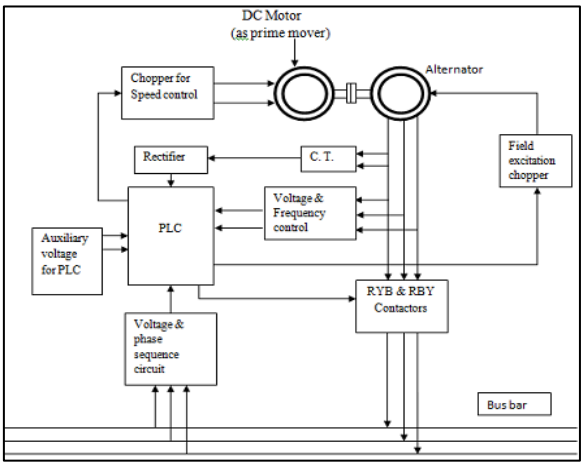

Fig. 2: Block diagram of PLC based alternator synchronization

Chopper for speed control is used to control speed of dc motor which is connected to alternator to synchronize the frequency with the bus bar. Field excitation chopper circuit is used to control excitation of alternator to synchronize voltage with the bus bar. PLC is used to compare, control and synchronize electrical parameters. RYB contactor is used for synchronization, when condition satisfies the RYB contactor will be ON. Voltage and frequency control is used for sensing of voltage and frequency from alternator output and feeding it to PLC. Voltage and phase sequencing unit takes phase voltage readings from bus bar and feeds to PLC.

B. Programmable Logic Controller

Fig. 3: PLC MicroLogix 1100 Controller

The MicroLogix 1100 controller is designed to broaden application coverage through embedded analog inputs, Ethernet communication, and visualization capabilities .MicroLogix 1100 controllers complement our low-end controllers for applications that require up to 144 digital I/O. Each MicroLogix 1100 controller contains 2 embedded analog inputs, with 10 digital inputs and 6 digital outputs. The controller can also expand its I/O capabilities by using the same modules as the MicroLogix 1200 controller. Up to four of the 1762 I/O modules can be used with a single MicroLogix 1100 controller.

Using the latest version of our world-class RS Logix 500 programming software, the MicroLogix 1100 controller can be programmed with an instruction set that is common with the MicroLogix and SLC 500 families of controllers. RS Logix 500 Starter, Standard, and Professional applications all support the MicroLogix 1100 controller, including its online editing capabilities.

C. PLC Program Structure

The main program performs the following functions.

1) Phase sequence detection
2) Alternator frequency measurement and its adjustment
3) Alternator voltage measurement and its adjustment, and
4) Synchronizing at zero phase difference condition

Flowchart of the main PLC program for auto synchronizing setup is shown below. Start the DC motor (prime mover). When the operator sees the prompt, he switches 'ON' the DC motor of the Alternator. Once the alternator is started, it develops some voltage at some frequency.

Following sequence of events will take place automatically.

1) Detection of phase sequence
2) Frequency measurement and control
3) Voltage measurement and control
4) Synchronizing

Flow chart of PLC programming logic

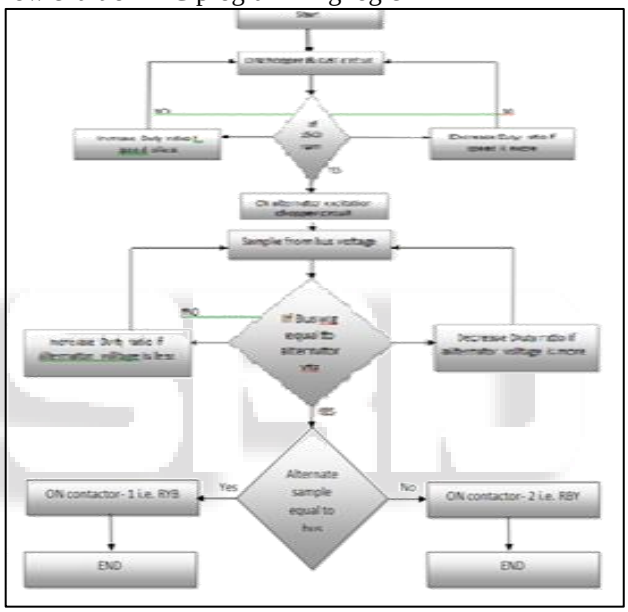

Fig. 4: Flow chart of PLC programming logic

IV. HARDWARE DETAILS

The hardware has been designed to fulfill all the requirements of the synchronizing process. A college trainer kit & we have design circuitis used as a controller for the setup. Also the figure showing the auto synchronizing setup consist of

1) Frequency control unit
2) Voltage control unit
3) Potential transformer unit
4) Chopper circuit unit
5) Phase sequence circuit.

A. Frequency Controlling Unit

The frequency of an alternator can be changed by varying the speed of the prime mover which is a DC shunt motor in this case .A chopper circuit is provided armature voltage control of the motor for this purpose.

B. Voltage Controlling Unit

Once frequency of alternator is fixed, or adjusted, its voltage is controlled by variation of excitation current. This excitation

current is varied by providing a chopper circuit in the field circuit of the alternator.

C. Potential Transformer Unit &Phase Sequence Circuit

This unit consists of a bank of four shell type transformer (P.Ts). Out of the four transformers thee are used for stepping down three phase voltages of alternator and the remaining one is used for stepping down the voltage of the phase Rof the bus bar. The potential transformers connected to the phase R of the bus bar and the phase R of the alternator are having two secondaries. Hence one secondary is used for voltage measurement and the other is used for phase detection circuit.

D. Voltage Measurement and Control

The digital output corresponding to the alternator and bus voltages are obtained by the following method. The busbar output and the incoming alternator output are first stepped down in the same ratio using P.T unit. These stepdown transformer signals are fed to the rectifier and filter circuits. The output from it is given to plc input.

E. Contactor with Switching Circuit

The contactor used as a synchronizing switch is in the form of a direct on line starter .In order to operate the contactor, its operating coil is connected to 230 V A.C supply through electromagnetic relay. The relay is activated at proper instant by the plc so that the contactor is closed at the correct in phase instant.

F. Chopper circuit

A chopper is a high speed “on" or “off” semiconductor switch. It connects source to load and load and disconnect the load from source at a fast speed. In this manner, a chopped load voltage as shown in Fig. is obtained from a constant dc supply of magnitude Vs. For the sake of highlighting the principle of chopper operation, the circuitry used for controlling the on, off periods is not shown. During the period Ton, chopper is on and load voltage is equal to source voltage Vs. During the period Toff, chopper is off, load voltage is zero. In this manner, a chopped dc voltage is produced at the load terminals.

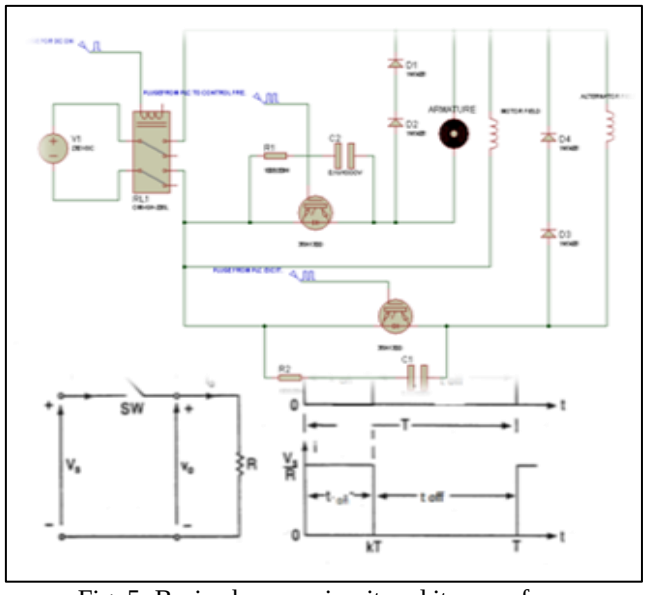

Fig. 5: Basic chopper circuit and its waveform

G. Phase sequence circuit

Phase sensing Circuit it consists of step down transformer, rectifier, and comparator and filter circuit as shown detail in next chapter. It sense wrong sequence and give the proper signal to the contactor so as to operate respective contactor. Control unit comprising of op amp circuit, power supply & sensor circuit which sense each phase and take the corresponding action. If any phase abnormal occurs it will give the corrected signal to the contactor. If any one of the phase absent or any phase voltage below 160V then both contactors will be absent so total load isolated from mains.

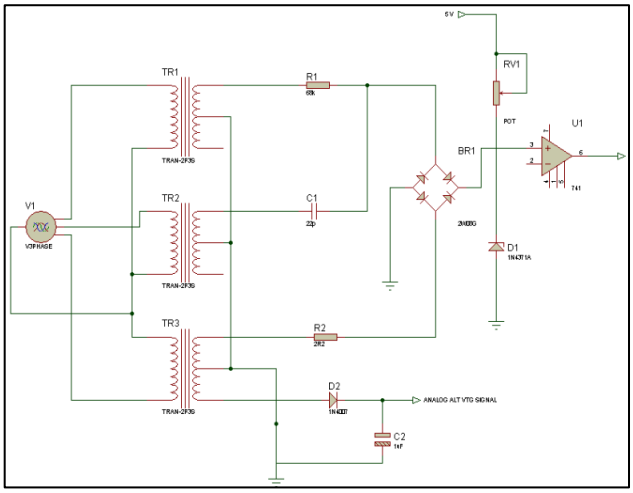

Fig. 6: Phase Sequence Circuit

V. Conclusion

The PLC based system of automatic synchronizer can be used more effectively compared to conventional methods of synchronization such as dark lamp method, bright lamp method, microprocessor, microcontroller, pc and synchronization using synchroscope this because of the fact that the conventional, method calls for of the operator and accuracy is less and it depends on the sense of correct judgment of the operator. Moreover the PLC based alternator synchronizing is convenient and requires less maintenance. It also exploits the advantage of superior performance like accuracy speed and reliability. Further this system can be controlled through SCADA, GSM, Data Acquisition System and various automatic controllers to control the load and automatic generation control without much human interference which will minimize the human errors and the system will be made more reliable.

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VI. REFERENCES

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