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Design of three phase power synchronizer

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Abstract

Synchronization is very useful to connect a power generation to a standard grid. Without a synchronizer it is impossible to maintain a power supply in any country. It is therefore essentially required to merge the multiple sources of electrical power generation to a single system so that overall load can be handled very easily in an organized way. So, the process by which the different generating units are tied by matching line voltage, frequency, Phase angle and phase sequence with each other is called synchronization. The synchronizer works on the principle of phase matching using zero cross detector, frequency matching and voltage matching. The phase voltage of synchronous generator and grid is measured using voltage measuring circuit that uses half bridge rectifier and sampled data is taken using microcontroller and displayed through it. In the same way, frequencies of both the generator and grid is measured using frequency measuring circuit in which the time difference of pulses of full wave rectifier is recorded by microcontroller unit and it is implemented to calculate frequency. The phase difference is calculated by phase detecting circuit. When the difference of voltage, frequency and phase are within the specified limit then relay is energized to operate the contactor and grid is successfully connected to synchronous generator. The probability of incorrect synchronization decisions is reduced due to the quickness and fault detection techniques of the microcontroller methodology, which is the research main contribution. As a result, the synchronization's dependability improves. For monitoring, measuring, and paralleling synchronous generators, the developed auto synchronization unit is rapid, cost - effective, incredibly reliable, and highly accurate.

Keywords: Three phase generator, Microcontroller, Fault detection, Synchronous generators, Zero Crossing Detector.

Introduction

A generator, transmission and distribution, and a large number of widely distributed loads comprise an electrical power system. They distribute the power generated to their respective loads in specific locations, forming separate island networks or stand-alone systems. Such systems have a number of issues, including[1]: i. A lack of power house generation capacity to supply its own load. ii. Surplus generation capacity, but additional power generation is ironically disposed using unproductive load rather than being used by end users. iii. Dysfunction of the system while supplying the target load. iv. Any MHP has the highest likelihood of being shut down if the national grid enters the area (i.e. system sustainability issue of MHP).

In many cases, more than one generator must be connected to the system. Increased reliability, expandability, flexibility, serviceability, and efficiency are some of the advantages of running multiple generators in parallel. Parallel operation allows generators to operate around their rated load, resulting in high efficiency[2].

When connecting a generator to a network of other generating units, the voltage, phase, and frequency at its terminals must meet the operating values. If the generator is allowed to link to the system outside of established safe levels, significant damage to the generator as well as system outages may arise. As a result, the auto synchronization machine is extremely crucial in generator synchronization. The primary issues with connecting a synchronous generator to an electrical system are establishing safe limits for each of the delta phase angle, delta frequency, and delta voltage magnitude[3].

The primary goal of this project is to connect small-scale generators in the most cost-effective way possible. This project is being carried out with the following goals in mind: i. A synchronous generator is used to generate power. ii. Various circuits are used to measure grid and generator frequency, voltage, and phase. iii. The measured output is analyzed using Arduino, and the contactor is controlled accordingly. iv. Contactor operation is implemented for automated synchronization. v. Evaluation of the impact of various SG excitation systems. vi. Detecting the phase angle and angular frequency during various abnormal grid conditions and power quality issues.

Methodology

The synchronizer operates on the phase matching principle, employing a Zero Crossing Detector and an exclusively OR (XOR) gate. Figure-1 depicts the automatic synchronizer's block diagram. The sinusoidal voltage generated by the SEIGs is stepped down and transformed into a correlating oscillatory square wave using ZCDs before being fed into the XOR gate. The XOR gate and relay are the main components of the phase matcher circuit[4]. When both inputs are the same, the output of this gate is low (i.e. when both the waves are synchronized). This synchronization signal is then sent to a relay, which activates the contractor switch. The signal from the relay drives the contractor.

This contractor has connections that are both normally open and normally closed. When the contractor is "on," two things happen[5]: i. The synchronizer circuit's power supply is turned off. ii. After synchronization, the generator and reference source are linked together.

The following steps comprise the event sequence for synchronization. i. More energy is supplied to the generator's shaft to bring it up to synchronous speed. ii. The generator's field is energized, and the voltage at the generator's terminals is measured and compared to the system. iii. The phase angle is contrasted. iv. The frequency of the generator is compared to the frequency of the grid. v. After matching the phase angle, frequency and voltage generator is tied with grid.

In order to resolve the issues listed above, the auto synchronizing device should carry out the following operations: i. To begin, When the potential difference between the two generators is above the allowable range, the device controls the voltage magnitude to minimize the potential difference. ii. Second, when the slip frequency between the two generators is not allowed, the device monitors it and regulates the frequencies to reduce it. iii. Third, When slip frequency is not permitted, the decisions are influenced the phase-angle variation between the two generators and alters the phases to minimize slip frequency.

Fourth, the closing order is issued when the frequency, voltage, and phase-angle meet the parallel requirements.

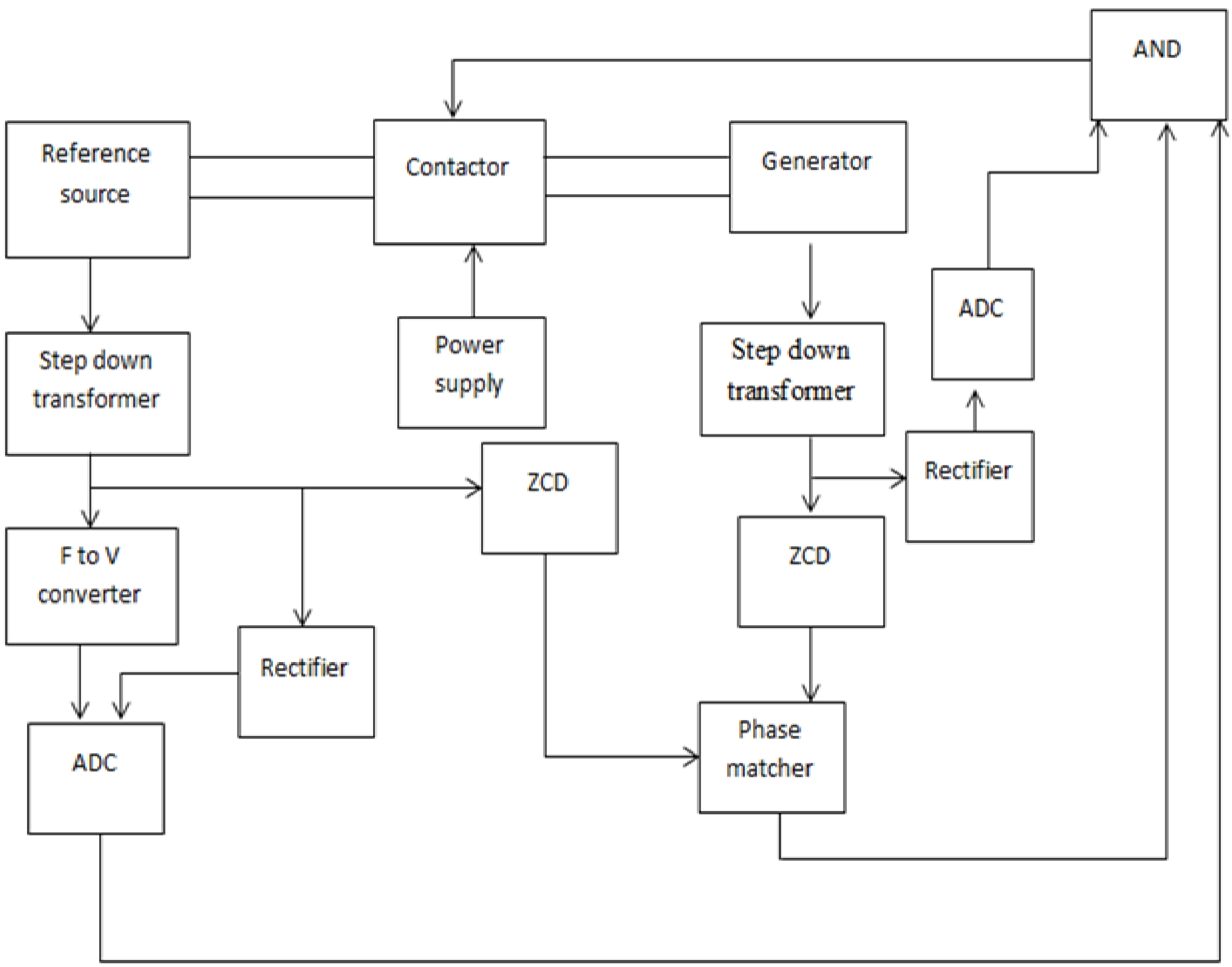

Figure-1: System Block Diagram.

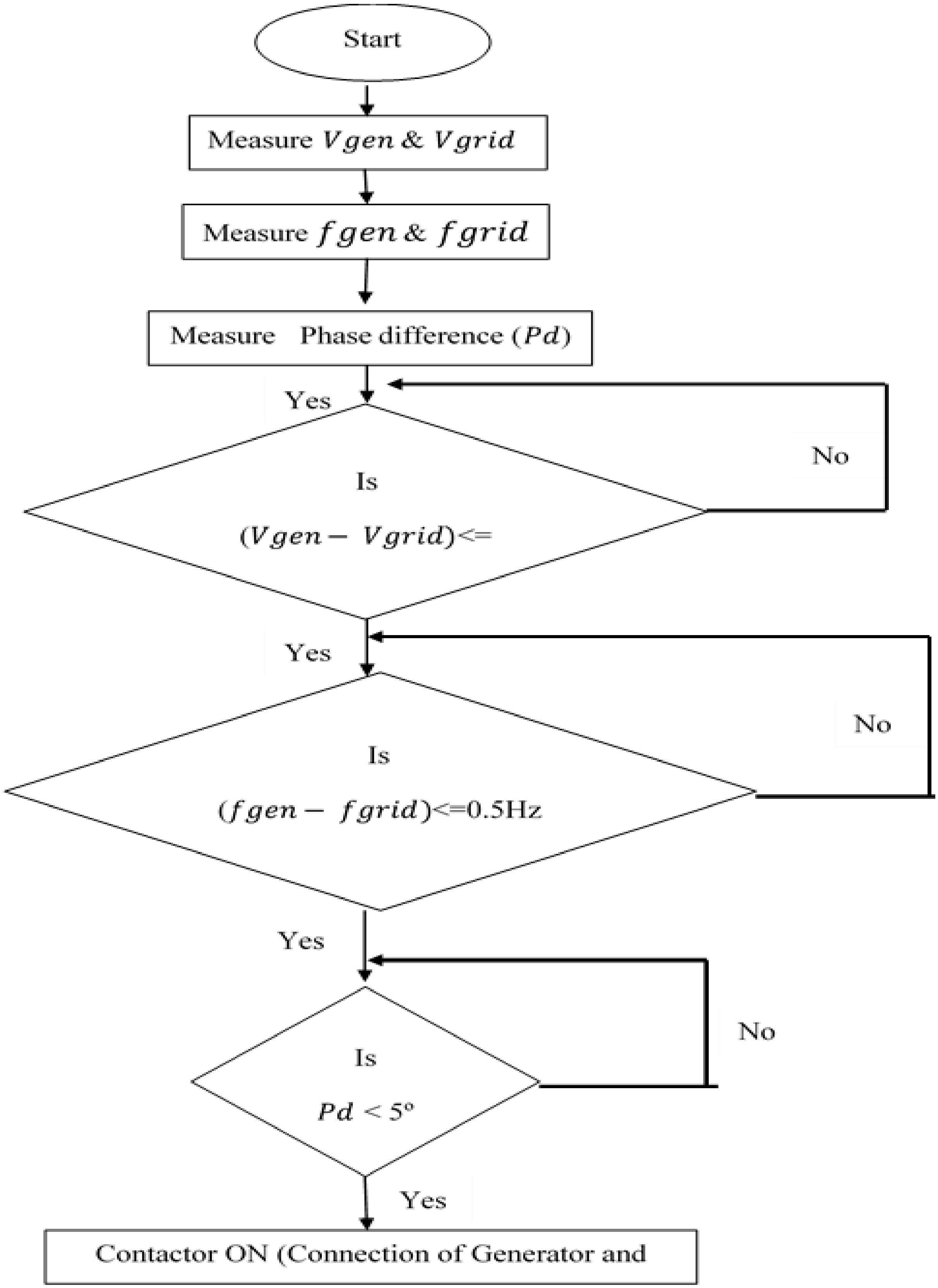

Figure-2: Flow Chart of System processing.

Results and Discussion

The basic design of our project is completed and the completed works are enlisted below: i. Design of zero cross detector and phase difference detection. ii. Design of voltage comparator. iii. Design of frequency matcher as well as frequency comparison with ADC.

In this circuit the source voltage is stepped down using the 6V transformer as shown in the circuit diagram above. Here the voltage obtain which is fed to the analog pin of Arduino (microcontroller)[6].

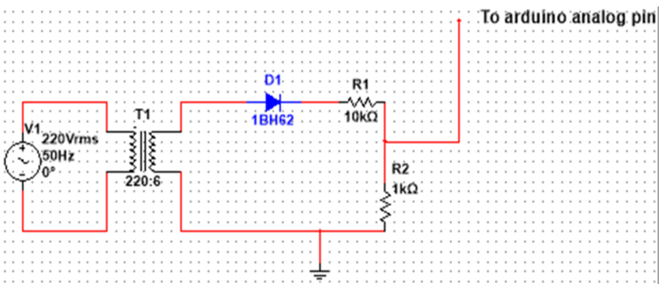

Figure-3: Voltage Measurement.

The voltage to be measured that is fed to microcontroller is given as below:

$$v_o = \frac{0.02727V_1R_2}{R_1 + R_2}$$

So if the input voltage is 220V rms then the voltage fed to microcontroller is given as:

$$v_o = 0.54\text{V}$$

The frequency measurement circuit is as shown in figure above. The circuit is zero cross detector circuit. The output of ZCD is fed to digital pin of the microcontroller. The time between consecutive zero detection is measured and recorded. Let say the time recorded is T, then the measured frequency is given as below[7]:

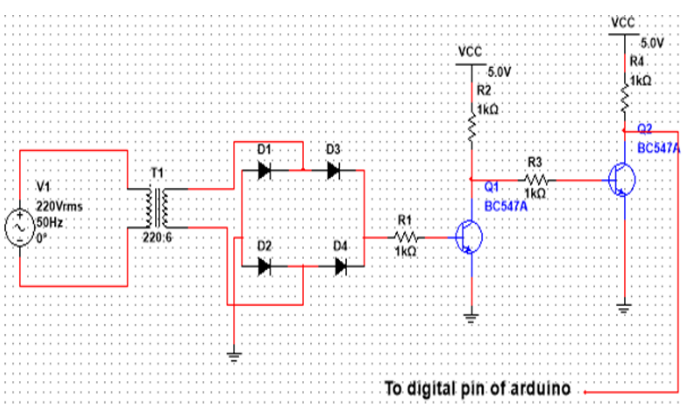

Figure-4: Frequency Measurement.

The frequency measurement circuit is as shown in figure above. The circuit is zero cross detector circuit. The output of ZCD is fed to digital pin of the microcontroller. The time between consecutive zero detection is measured and recorded. Let say the time recorded is T, then the measured frequency is given as below:

$$f = \frac{1}{2T}$$

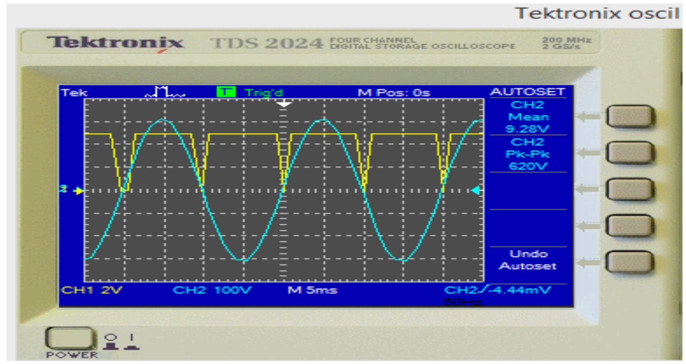

Figure-5: Zero Cross Detection in NI Multisim simulation.

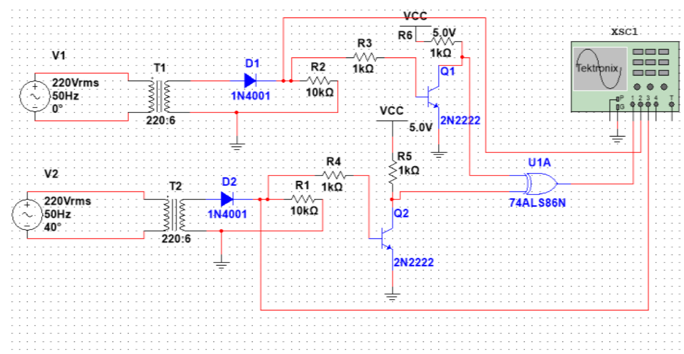

Figure-6: Design of ZCD and phase difference detection circuits.

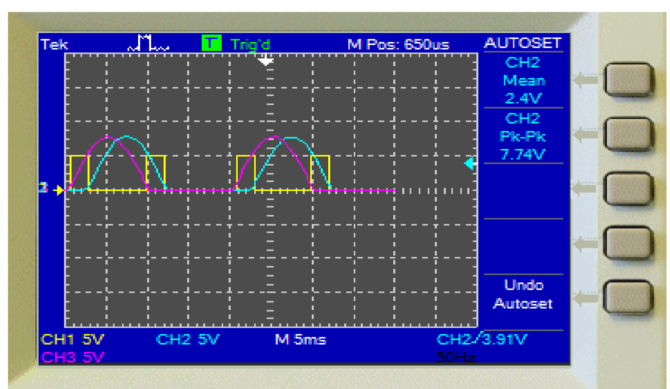

Figure-6: Phase Detector simulation.

Design of voltage comparison circuit: The magnitude of the sinusoidal voltage produced by the generator must be equal to the magnitude of the sinusoidal voltage of the grid. To compare the voltage first the stepped down signals are rectified by using full wave rectifier. Since we have use 6-0-6 transformer to step down the signal, the rectified signal which is to be compare by using ADC in microcontroller is 6V dc for input voltage of 220V which is not read by microcontroller. So, we have to reduce this rectified voltage to certain value (less than 5V). This reduction is achieved by using voltage divider.

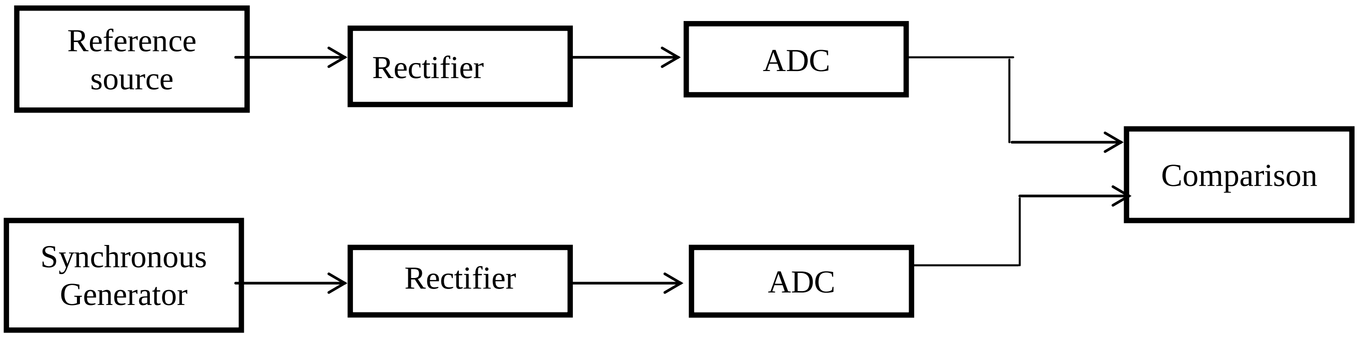

Figure-7: Block diagram for voltage comparison.

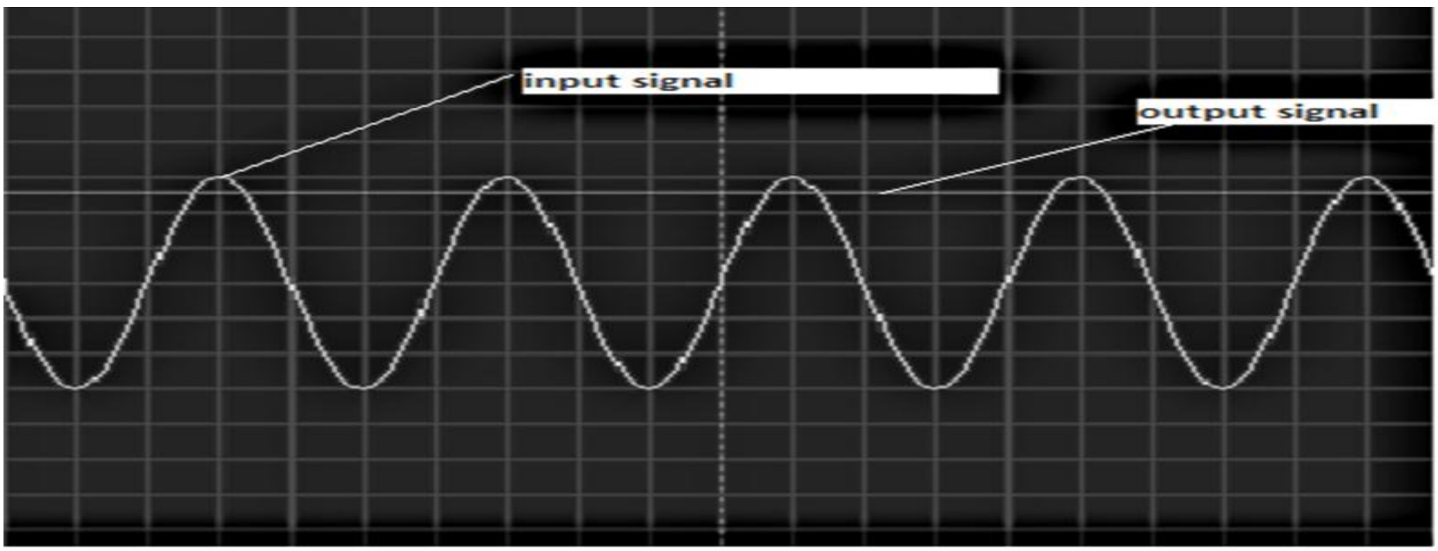

Figure-8: Waveform of voltage comparison.

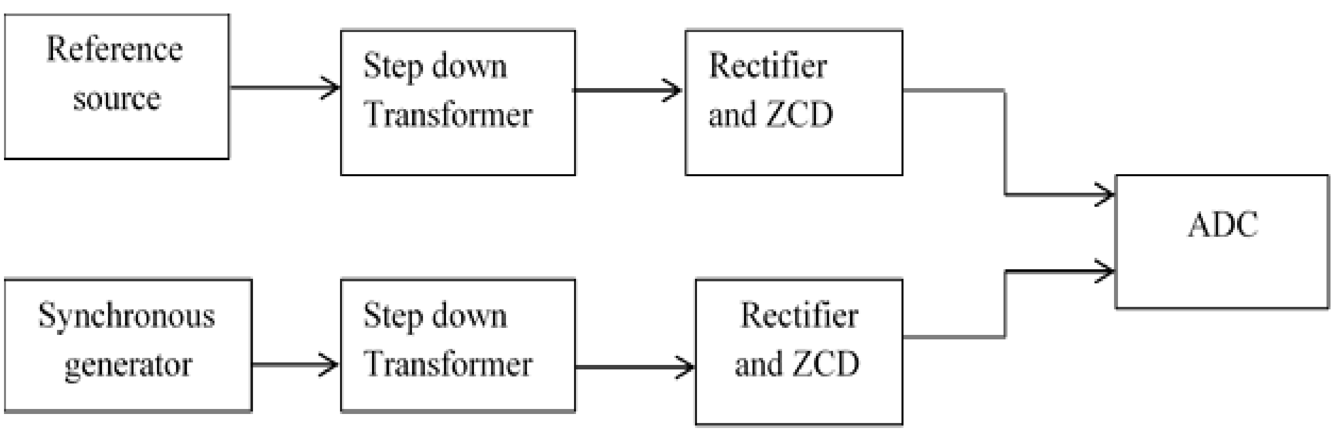

Figure-9: Block diagram of frequency matching.

Conclusion

The process by which the different generating units are tied by matching line voltage, frequency, Phase angle and phase sequence with each other is called synchronization. Hence, the inter-connection via mini-grid using synchronizer assists in power sharing and saving opportunities as well as system stability and supply reliability increasing the life span and economic viability of the plant.

References

1. Bell, K., & Gill, S. (2018). Delivering a highly distributed electricity system: Technical, regulatory and policy challenges. *Energy policy*, 113, 765-777.

2. Sen, S., Mazumder, P., Jamil, M. H., & Chowdhury, R. (2014). Design & construction of a low cost quasi automatic synchronizer for alternators. *International Journal of Engineering Research*, 3(5).

3. Bensalah, A., Barakat, G., & Amara, Y. (2022). Electrical generators for large wind turbine: Trends and challenges. *Energies*, 15(18), 6700.

4. Chakraborty, C., Bhadra, S. N., & Chattopadhyay, A. K. (1999). Analysis of parallel-operated self excited induction generators. *IEEE transactions on energy conversion*, 14(2), 209-216.

5. Ahshan, R., Iqbal, M. T., & Mann, G. K. (2007). Power resistors based soft-starter for a small grid connected Induction Generator based wind turbine. In Proceeding of The The Seventeenth Annual Newfoundland Electrical nd Computer Engineering Conference, 1-5.

6. Carlson, R., & Voltolini, H. (2008). Grid synchronization of brushless doubly fed asynchronous generators in wind power systems. In The International Conference on Electrical Engineering, Vol. 6, No. 6th International Conference on Electrical Engineering ICEENG, 1-10. Military Technical College.

7. Farret, F. A., & Simões, M. G. (2006). Integration of alternative sources of energy. Piscataway, NJ, USA: IEEE press. Vol. 504.