# Development of a Synchronization Meter for a Grid-connected Small Scale Solar PV Applications

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**Abstract.** Double Frequency Meter and Synchronescope are the most widely used instruments to detect or measure synchronization parameters on two sources of electrical voltage, but in reality the prices of these tools tend to be more expensive. This paper discusses the synchronization process detection tool used on a grid connected inverter with a grid/PLN main source. The instrument is equipped with a synchronous and asynchronous condition indicator, a microcontroller and an LCD Human Machine Interface Nextion. Several experiments have been carried out from the proposed design and the results are compared with standard measuring instruments. Thus, the results are close to the real value and are able to detect synchronous and asynchronous conditions of both voltage sources.

**Keywords:** double frequency meter, synchronization, grid connected inverter, inverter

## 1    Introduction

In recent decades, along with the depletion of primary energy sources and the increasing demand for human energy, alternative energy sources in the form of solar PV have increased in popularity as a renewable energy source. This is evidenced by the increasing trend of PV installations in several countries. In order to meet energy needs, the output voltage of the solar PV inverter can be paralleled with the main voltage source, namely the grid/PLN.[1].

Parameters in the process of synchronizing the two voltage sources must be ensured that the value of voltage, frequency, and phase angle between the two voltage sources is the same [2]. We can use a detection sensor that is designed to be able to detect the value of these parameters both under the same conditions and when there is a difference in the reading value [3].

Popular measuring instruments used in the voltage synchronization process are the double voltmeter, double frequency meter and syncoscope [4]. But the high cost of the equipment is still a weakness [5]. Thus developing a synchronization detection tool for detection on a grid-connected inverter with a grid main source is very important in the process of paralleling the two sources [6] and [7] there have been many studies discussing synchronization detection tools. The method used is a voltage sensor and a sine wave zero point detection sensor [8].

Detection of synchronization parameters with voltage sensors and zero crossing has been widely used [9]. The instrument developed consists of a voltage sensor, a zero crossing sensor and an Arduino Uno microcontroller. Based on the sensor readings used, the detected parameters are compared and displayed on the Nextion LCD for detection of synchronous and asynchronous conditions of the two voltage sources.

The purpose of this research is to develop a complex and inexpensive means of detecting the synchronization process. The detected parameter values are used to provide indicators on the operating system. The voltage sensor is used to read the voltage and frequency values as well as the zero crossing sensor to detect the value of the sine wave shift and is displayed in the value of the phase angle of the two sources and then processed in the microcontroller and displayed on the Nextion LCD.

Here is how this paper is structured: Section 2 describes the synchronization process. Describes in detail the proposed system for the detection of voltage synchronization parameters in Section 3. Section 4 test results and. Part 5 conclusion

## 2      Synchronization Process

### 2.1      Synchronization

Synchronization is the process of equalizing the voltage, frequency, phase angle and phase sequence between two AC power sources. In this discussion, the two AC power sources in question are in the form of voltages that come from the main source, namely PLN and from a second source, namely the output voltage of the inverter from the Solar Power Generation System, therefore before synchronizing must be known in advance about the parameters and also synchronization methods.

### 2.2      Sync Parameters

In the synchronization process between the PV mini-grid output voltage and the grid, there are several parameters that become a reference that a system has gone through a synchronization process, including the equation of the following parameters.

a)  Frequency
    The PLTS output frequency and the system frequency (PLN) must match. In general, the frequency used is 50 or 60 Hz in accordance with international standards. In Indonesia, the frequency of 50 Hz is used as an indicator of work under normal conditions. The permissible frequency tolerance value is ± 0.2 Hz under normal

conditions. In the network, a frequency limiter is installed which limits the frequency to a minimum of 48.5 Hz and a maximum of 51.5 Hz.

b) Voltage

Voltage The second parameter that must be met is voltage. In the synchronization process, the voltage on the PLTS and PLN networks must be the same. The measuring instrument is a double voltmeter. Between the generator voltage (which will be in parallel) with the network system voltage must be the same magnitude (value). The allowable voltage variation between the two systems is ± 5% of the nominal voltage.

c) Phase Angle

Often there is confusion between phase and frequency differences. Frequency is the number of cycles (sinusoids) in one second of an electrical circuit. While the phase difference is the angular shift between one circuit and another for the same phase. To see the phase difference graphically, an oscilloscope is needed. But in practice it becomes impractical to install an oscilloscope on an electrical panel (alternator). Instead, a synchroscope and lamp are installed to detect this phase difference. In this synchroscope, only "slow" and "fast" information is shown, as well as points or lines that lie between them. If the needle points towards the slow, it means that the alternator phase is lagging behind the system phase, while if the needle points towards the fast, it means that the alternator phase is faster than the system phase. The difference between the unsynchronized phase angle and the synchronized phase angle

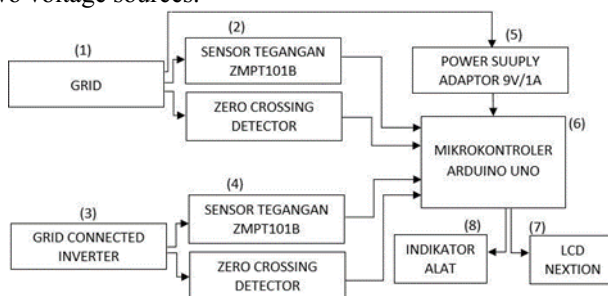## 2.3 Synchronous and Asynchronous Conditions of Inverter With Grid

PLTS which is connected to the network (on-grid) uses an inverter that can synchronize with the PLN network on parameters such as voltage, frequency and phase difference. If these parameters are not in sync, then the electrical power generated by PLTS cannot be connected to the PLN network. However, when the supply of the PLN network goes out due to interference or maintenance, the on-grid PLTS also cannot operate due to the absence of a synchronization reference for the inverter. Synchronous condition, defined as a condition where both voltage sources from both the inverter and the grid have the same amplitude, frequency and phase voltage/current, this principle is indispensable in parallel operation. The same is true for inverters. If the characteristics of the electrical power generated by the inverter are out of sync, it is possible that parallel operation will result in instability and even failure of the synchronization process. Therefore, based on SPLN D3.022-2:2012, the PLTS on grid inverter designed must also have the following protections:

1. Over/Under Frequency, the inverter must be able to maintain the output frequency within the allowed frequency range. in Indonesia the frequency range is maintained at 50±0.2 Hz except for short transient periods 50±0.5 Hz is permitted.

2. Over/Under Voltage, the inverter must be able to maintain the output voltage within the allowable range. in Indonesia the allowable voltage range is 230 Volt -10%, +5% Over/Under Voltage, the inverter must be able to maintain the output voltage
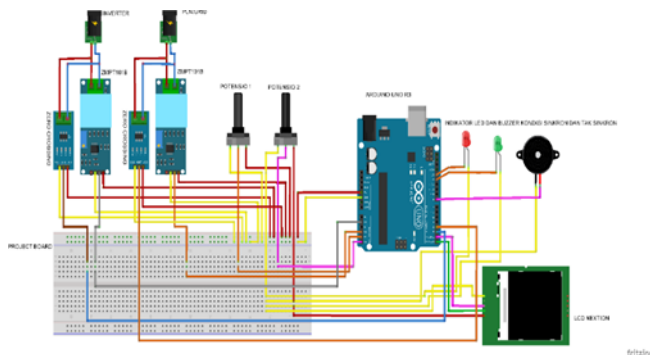
within the allowed range. in Indonesia the allowable voltage range is 230 Volt - 10%, +5%

## 3      Methodology

Figure 1 illustrates the block diagram of the system that includes.[1] and [3] a voltage source to be paralleled,[2] and [4] a zmpt101b voltage sensor and a zero crossing detector, [5] an adapter as a microcontroller power supply and,[6] a microcontroller,[7] an LCD Nextion Voltage. The output of the grid-connected inverter and the grid voltage are detected by two ZMPT101B voltage sensors and the Zerro Crossing Detector. The sensor readings are processed on the microcontroller and the synchronization parameters are displayed by the Nextion LCD, namely the voltage value, frequency and phase angle of the two voltage sources.



**Fig. 1.** The system's block diagram



**Fig. 2.** The system's electrical circuit

Figure 2 shows a picture of a voltage synchronization detection device. Positive (+) and negative (-) inputs from the zmpt101b voltage sensor and the zero crossing detector sensor are connected to both voltage sources and the ZMPT101B sensor output to the analog input of the microcontroller and the zero crossing detector sensor output is connected. on the interrupt pin of the microcontroller. Nextion LCD on the RX and TR pins of the microcontroller. While the indicator is connected to the digital out pin of the microcontroller.

**Table 1.** The component's parameters

| Components | Spesification |
|---|---|
| Voltage Sensor | Ip = 2 mA |
| | Is = 2 mA |
| | Turn Ratio= 1000:1000 |
| | Toleransi Kesalahan = -0.5% |
| | ≤ f ≤ 0(input 2mA,sampling resistor 100Ω) |
| | Tegangan    Toleransi= |
| | 4000V |
| Zerro Crossing Detector | Input 220,50Hz |
| Microcontroller | Arduino Uno |
| LCD touchscreen | Nextion, 3,2 inch |

## 4    Results And Discussion

The prototype developed consists of an isolated circuit protected by a box and cover made of 3D printing with polylactic acid material, the top surface of the tool consists of a Nextion LCD, indicators and potentiometers.

The design process for the tool, program and hardware of the voltage synchronization detection tool is shown on the flochart in the following figure. Starting from the design of the box, then the selection and manufacture of sensors and programs. Test calibration parameter detection and Nextion LCD display
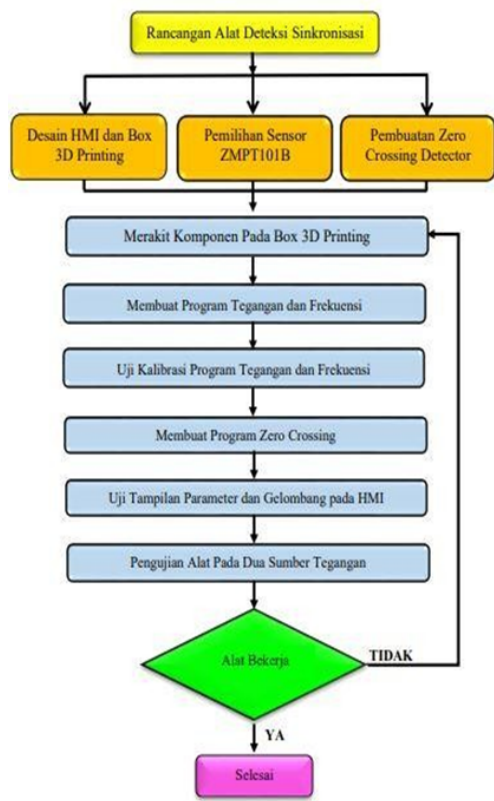
**Fig. 3.** Synchronization detection tool creation flowchart



**Fig. 4.** Photo sync detection tool

Data is collected simultaneously using conventional and standard measuring instruments, namely the fluke readings from the voltage synchronization detection tool compared to conventional measuring instruments, the smaller the error value that is read, the better the detection ability and parameter reading is carried out by the detection tool.

The instrument calibration test is carried out with two voltage sources, namely the voltage source from the output of the grid-connected inverter and the grid voltage which is input to the input of the voltage synchronization detection tool. Data were taken for 2 days on the inverter and the grid at the Malang State Polytechnic. The detection results of the synchronization parameter values can be read on the Nextion LCD scree

**Table 2.** Grid voltage data

| Grid Voltage Reading Results | | |
|---|---|---|
| No | Fluke (V) | Grid Voltage Sensor (V) | Error (%) |
| 1 | 231,1 | 232,20 | 0,47 |
| 2 | 231,2 | 232,95 | 0,75 |
| 3 | 231,0 | 232,23 | 0,53 |
| 4 | 231,4 | 230,62 | 0,34 |
| 5 | 231,5 | 232,60 | 0,47 |
| 6 | 231,8 | 232,55 | 0,32 |
| 7 | 231,9 | 232,72 | 0,35 |
| 8 | 230,2 | 231,35 | 0,50 |
| 9 | 231,7 | 232,35 | 0,30 |
| 10 | 229,3 | 230,15 | 0,37 |
| Average value of error | | | 0,44 |

**Fig. 5.** Graph of detection tool reading results on grid voltage

**Table 3.** Data inverter voltage

| No | Fluke (V) | Grid Voltage Sensor (V) | Error (%) |
|---|---|---|---|
| | | Voltage Reading Results Inverter | |
| 1 | 224,3 | 223,93 | 0,16 |
| 2 | 224,0 | 229,88 | 2,63 |
| 3 | 223,8 | 228,64 | 2,16 |
| 4 | 225,2 | 229,64 | 1,97 |
| 5 | 227,1 | 232,09 | 2,20 |
| 6 | 227,5 | 230,08 | 1,13 |
| 7 | 228,0 | 229,45 | 0,64 |
| 8 | 228,0 | 229,05 | 0,46 |
| 9 | 228,6 | 232,95 | 1,90 |
| 10 | 228,9 | 232,65 | 1,64 |
| Average value of error | | | 1,50 |

**Fig. 6.** Graph of readings of detection tool at inverter voltage

**Table 4.** Grid frequency data

| | | Grid Frequency Reading Results | |
|---|---|---|---|
| No | Fluke (Hz) | Grid Fre-quency Sensor (Hz) | Error (%) |
| 1 | 49,98 | 50,04 | 0,12 |
| 2 | 50,02 | 50,02 | 0,00 |
| 3 | 49,96 | 50,00 | 0,08 |
| 4 | 50,05 | 49,99 | 0,12 |
| 5 | 49,99 | 50,02 | 0,06 |
| 6 | 50,02 | 50,08 | 0,12 |
| 7 | 50,01 | 50,06 | 0,10 |
| 8 | 49,99 | 50,06 | 0,14 |
| 9 | 50,03 | 50,05 | 0,04 |
| 10 | 50,02 | 50,05 | 0,06 |
| Average value of error | | | 0,08 |

**Fig. 7.** Graph of detection tool reading results at grid frequency

**Table 5.** Inverter frequency data

| Grid Frequency Reading Results | | | |
|---|---|---|---|
| No | Fluke (Hz) | Grid Frequency Sensor (Hz) | Error (%) |
| 1 | 49,96 | 49,99 | 0,06 |
| 2 | 50,02 | 50,01 | 0,00 |
| 3 | 50,02 | 49,98 | 0,08 |
| 4 | 50,05 | 50,02 | 0,06 |
| 5 | 50,02 | 50,00 | 0,04 |
| 6 | 50,01 | 50,03 | 0,04 |
| 7 | 50,02 | 50,05 | 0,06 |
| 8 | 49,98 | 50,05 | 0,14 |
| 9 | 50,02 | 49,98 | 0,08 |
| 10 | 49,99 | 50,02 | 0,06 |
| Average value of error | | | 0,06 |

**Fig. 8.** Graph of detection tool readings at inverter frequency
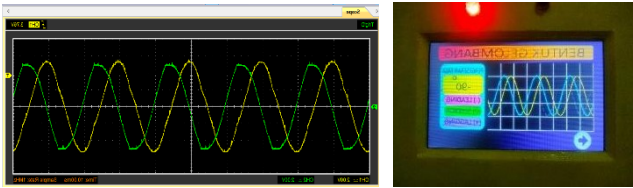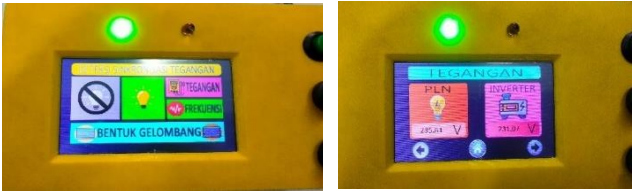


**Fig. 9.** 0° . Phase angle value display



**Fig. 10.** 90° . Phase angle value display



The detection tool experiment was carried out in two conditions of grid-connected inverter output voltage and grid voltage in synchronous and asynchronous conditions and the parameter display displayed on the Nextion LCD. From the results of testing the tool on a synchronous voltage

source, it was found that the tool has been able to work well by displaying parameters in the synchronization process in the form of voltage values, frequency values and sine waves from the two sources on the Nextion LCD. And the indicator on the LCD in the start menu as well as the green LED as an indicator of the synchronous condition are also well lit.



**Fig. 11.** Experiment on synchronous conditions

Based on the test results that have been carried out, the voltage synchronization detection tool has been able to display parameters in the form of voltage values, frequencies, waveforms with a phase shift difference or phase angle between the two voltage sources on the Nextion 3.2 inch LCD screen. And the results of the calculation of the error value in the two-day test, the voltage error value is only 1.68% at the grid voltage, and 2.63% at the inverter voltage, and 0.22% at the grid frequency and 0.14% at the inverter frequency.

## 5      Conclusion

This study proposes a method to detect the synchronization process at the output of a grid-connected inverter with a grid voltage source and can display parameters on the Nextion LCD by using a voltage sensor and a zero crossing detector sensor as a detector of voltage, frequency, and phase angle values from both sources. This method is a development of conventional tools that already exist in order to obtain a minimal cost value but still according to its normal function. Due to the simple shape and design, this development tool is only installed on a solar power generation system that is connected to the grid so as to facilitate the process and monitoring of synchronization that occurs in a parallelized electrical system.

## 6      Acknowledgement

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