The American Journal of Engineering and Technology
ISSN 2689-0984 | Open Access

TYPE Original Research
PAGE NO. 53-56
DOI 10.37547/tajet/Volume07Issue08-06

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Automatic phase selection devices: analysis and development prospects

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OPEN ACCESS

SUBMITTED 11 June 2025
ACCEPTED 07 July 2025
PUBLISHED 09 August 2025
VOLUME Vol.07 Issue08 2025

CITATION

Rakhimov Mirkamol Farkhodjon ugli, & Doniyor Tursunov Abdusalimovich. (2025). Automatic phase selection devices: analysis and development prospects. The American Journal of Engineering and Technology, 7(8), 53–56. https://doi.org/10.37547/tajet/Volume07Issue08-06

Abstract: This paper analyzes automatic phase selection devices (APSD) used to ensure reliable power supply for single-phase consumers in three-phase electrical networks. Existing devices are classified into digital and analog types, and their schematic structures, operating principles, and application areas are examined. The results show that while digital APSDs provide higher accuracy and adaptability, they have a more complex structure and higher cost. Analog devices are simpler and cheaper but cannot effectively mitigate voltage unbalance in modern grids. Currently, due to the large-scale integration of single-phase photovoltaic (PV) inverters into the grid, the issue of voltage unbalance has become more pressing. Therefore, this paper proposes the development of a new generation of APSDs capable of calculating the unbalance factor, automatically selecting the optimal phase, and performing real-time monitoring.

Keywords: System automatic phase selection device, voltage unbalance, digital APSD, analog APSD, voltage sensor, photovoltaic inverter, optimal phase selection, three-phase network.

Introduction: The Modern power distribution systems require stable and uninterrupted supply to consumers. Voltage fluctuations, phase loss, and load imbalance in three-phase networks can cause significant degradation of power quality and lead to equipment damage. Automatic phase selection devices (APSD) are widely applied to ensure supply reliability, especially for single-phase consumers connected to three-phase grids. These devices monitor the condition of all phases, determine the most stable one, and automatically switch the load to it, thereby improving supply quality and preventing interruptions [1–10].

Recent studies indicate that with the increasing integration of single-phase photovoltaic (PV) inverters into distribution networks, voltage unbalance has become a more critical issue [6–9]. Conventional APSDs mainly detect voltage presence or level but do not consider real-time load balancing across phases. This calls for advanced, adaptive solutions capable of both phase selection and voltage unbalance mitigation.

METHODOLOGY

The study is based on comparative analysis of existing APSD designs described in [1–10]. Devices are classified into two main categories:

- ❖ Digital APSDs (microcontroller-based)
- ❖ Analog APSDs (comparator-based)

2.1. Digital Phase Selection Devices. In digital phase selection devices, microcontrollers are used to perform control operations, and information regarding the device status is transmitted to a display unit [1,2,6–10]. The circuit designs of such devices may vary depending on additional functions and components. Digital phase selection devices can be classified into three categories:

- Standard phase selection devices;
- Network–generator phase selection devices;
- Voltage sensor-based phase selection devices.

The standard phase selection device, illustrated in Figure 1, consists of the following elements. Each phase is connected to a step-down transformer, which typically reduces the voltage from 220 V to 12 V. The subsequent stage converts the alternating voltage into direct voltage, which is then regulated through voltage control elements to provide the required operating voltage for the microcontroller. The microcontroller compares the phase voltages, transmits the results to the display, and controls the relays. The relay block serves to connect or disconnect the load [1,2,10].

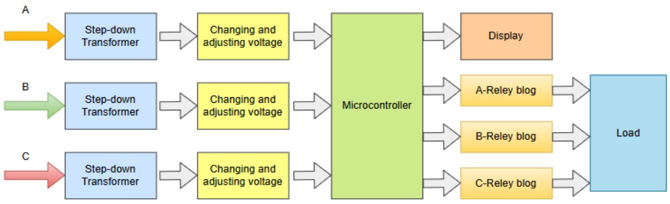

Figure 1. Block diagram of a standard phase selection device [1,2,10].

Network–generator phase selection devices are designed to provide additional power supply to the consumer when the network phase voltages are outside the specified range. An example of such a device is shown in Figure 2 [7].

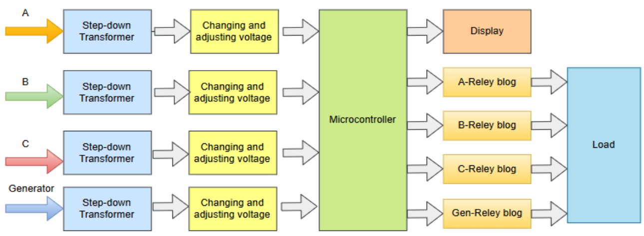

Figure 2. Block diagram of a network–generator phase selection device [7].

To further improve the operational reliability of this type of phase selection device, a network–generator phase selection device with a backup power source, as illustrated in Figure 3, has been developed [8].

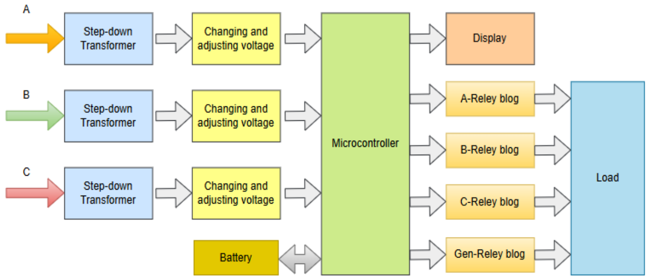

Figure 3. Block diagram of a network–generator phase selection device with a backup power source [8].

Voltage sensor-based phase selection devices do not use step-down transformers to detect network voltage and transmit signals to the microcontroller. Instead, voltage detection is performed through voltage sensors directly connected to the network and voltage divider circuits [6,9]. The number of relays used in such devices is typically either three or six.

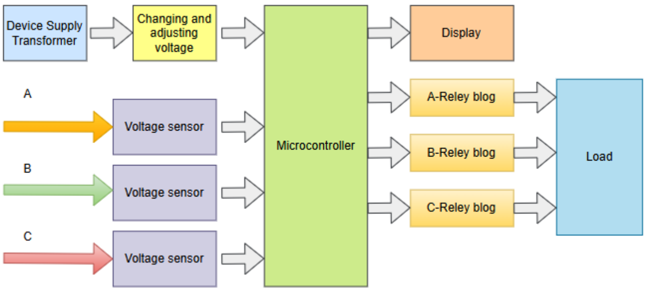

Figure 4. Block diagram of a voltage sensor-based phase selection device with three relays [9].

Figure 4 presents the schematic of a three-relay voltage phase selection device, in which the device is powered through a step-down transformer [9]. Figure 5 illustrates a six-relay voltage sensor-based phase selection device, where the load is distributed across all three phases [6].

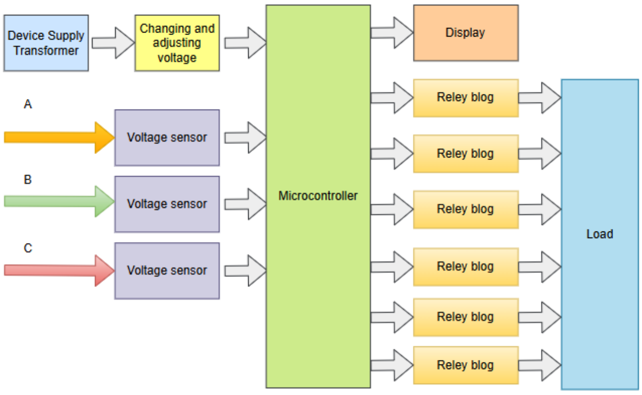

Figure 5. Block diagram of a voltage sensor-based phase selection device with six relays [6].

2.2. Analog Voltage Sensor-Based Phase Selection Device. The analog voltage sensor-based phase selection device is shown in Figure 7. In this device, voltage is detected using voltage sensors and transmitted to the voltage comparison block [3]. While in the analog phase selection device shown in Figure 6 the load is supplied through three relays [4,5], in Figure 7 the load is supplied through four relays. The fourth relay serves to connect or disconnect an auxiliary power source [3].

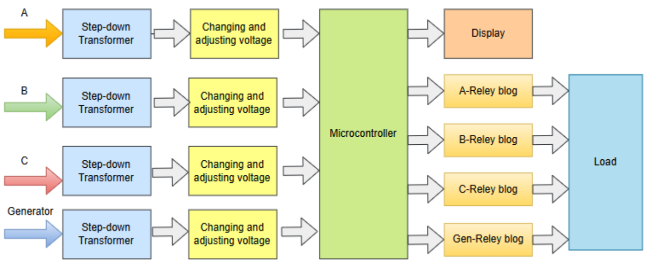

Figure 7. Analog voltage sensor-based phase selection device [3].

Although the above analog phase selection device circuits are simpler, they lag behind digital phase selection devices in terms of user information and measurement accuracy.

RESULTS

Analysis shows that:

- Digital devices provide higher accuracy, adaptability, and user information but require more complex circuitry and higher costs.
- Analog devices are simpler and cheaper but lack advanced monitoring and adaptability.
- Voltage sensor-based designs remove the need for

step-down transformers, reducing size and potentially improving response time.

- ➢ Network–generator integrated designs ensure uninterrupted power during phase loss but increase system complexity.

Recent developments, such as the "smart phase selector" proposed by Khojiakbar et al. (2023) [9], incorporate algorithms for optimal load-phase allocation, which is particularly important in PV-integrated grids. Statistical analysis by Ilunga et al. (2023) [6] further supports that APSDs can significantly improve voltage stability and reduce unbalance when properly designed.

DISCUSSION

Traditional APSDs effectively maintain supply continuity but are not optimized for emerging challenges such as:

- ➢ High penetration of single-phase PV inverters;
- ➢ Increased load asymmetry in low-voltage networks;
- ➢ Need for dynamic voltage unbalance mitigation.

To address these, next-generation APSDs should integrate:

- ✓ Real-time voltage monitoring for all three phases
- ✓ Voltage unbalance factor calculation;
- ✓ Automatic PV inverter phase reallocation;
- ✓ LCD-based monitoring and intelligent control algorithms.

Such systems would not only maintain supply reliability but also contribute to energy efficiency and grid stability in renewable-rich environments.

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