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Improving a no-failure operation of a PV systems with grid inverters

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Problem statement

Electrical energy produced at micro generation facilities, including PV systems, that is not consumed by the owners can be employed as according to the adopted law No. 471-FZ dated December 27, 2019 ‘On Amendments to the Federal Law ‘On the Electric Power Industry’ in the part regarding the amplification of micro generation’. A number of factors can specify the amount of electricity to be sold, as for instance the duration of PV systems downtime due to elements failures. Therefore, researching the aspects to improve the no-failure operation of PV systems seem to be relevant.

The subject of the study is the no-failure operation of a PV system connected to the power grid.

The purpose of the study is to measure the no-failure operation of a PV system with a string inverter and micro inverters.

The aims were to:

1. Analyze two options of structural patterns of PV systems: with a string and a micro inverter;
2. Build a fault tree for each of the options analyzed for structural patterns of PV systems;
3. Make up expressions to calculate the probability of PV systems failure;
4. Do mathematical modelling of the reliability of a PV system using the data on the reliability of its elements.

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Solution methods

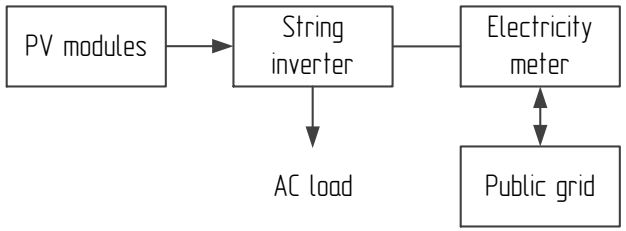


Figure 1. PV system with string inverter structural pattern

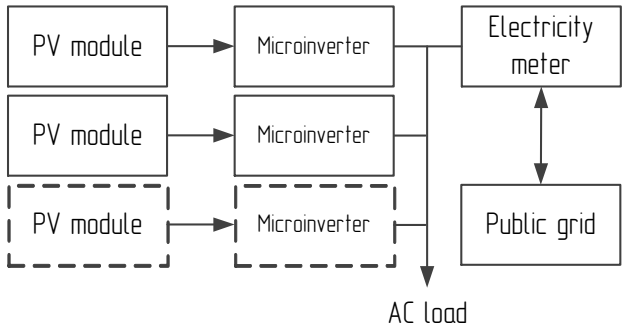
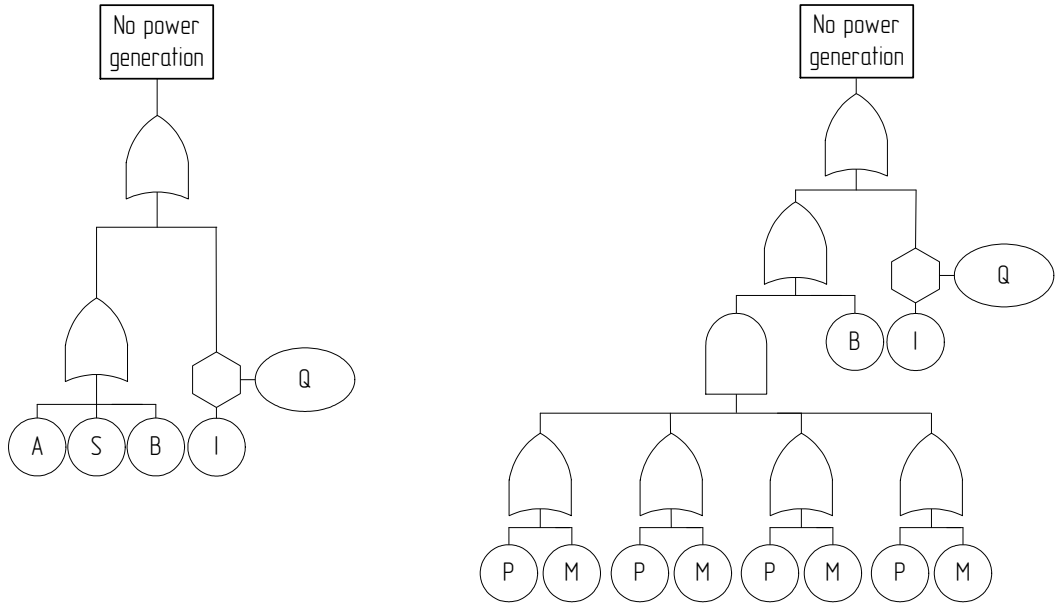


Figure 2. Scheme of a PV system with micro inverters

The highest value of failure rate is typical for the string inverter in the system under study (figure 1). Failure of the string inverter may lead to disconnecting of PV panels from the grid. Therefore, one of the options to improve the reliability of a PV system is to use a micro inverter instead of a string inverter (figure 2).

A fault tree was built for each of the two PV system options (figure 3), that encompassed 16 PV modules. Figure 3b shows the fault tree for the system option with micro inverters (4 PV modules are connected to each micro inverter). Two groups of events were taken into account while building the fault tree: those happening when insufficient insolation occurs, in terms of the possibility of electrical energy supply to the grid, and sufficient insolation. The latter included events associated with failures of switching devices, inverters, and PV modules. Resulting from a fault tree construction, the authors obtained expressions to calculate the probabilities of failures of systems with a string inverter, and with micro inverters.

Symbols in the figure 3: A – PV array; S – string inverter; B – AC circuit breaker; P – PV modules; M – micro inverter; I – PV system failure due to reduced insolation; Q – restrictive condition, characterized by the magnitude of the probability of insufficient insolation.



a b

Figure 3. Fault trees
a) system option with string inverter; b) system option with micro inverter.

Conclusions

1. The authors built a fault tree (complete cessation of electrical energy supply) for various options of PV systems: with a string inverter, and with micro inverters. They obtained expressions to calculate the failure probability for the options studied of PV systems, taking into account the number of PV modules that can be connected to one micro inverter, as well as the number of circuits of PV modules and their number in the circuit.
2. The authors have performed mathematical modeling of the PV system reliability with 16 PV modules for the climatic conditions of the central part of Mari El Republic. Thus, they obtained the values for the PV systems failure probability for the periods of 1 year and 10 years. The probability of a complete termination of the electrical energy supply to the grid with an increase in the duration of a period of PV system operation both with a string inverter and micro inverters increases; however, for the latter version of the system, the failure probability remains less possible than the corresponding probability for a system with a string inverter. The use of micro inverters that can be connected with only one PV module provides the best reliability of the PV system as to electrical energy supply to the grid. The use of micro inverters that can be connected with several PV modules allows for reducing the possibility of a complete cessation of electrical energy supply to the grid compared to the option of a PV system with a string inverter; meanwhile, the reliability of the PV system does not differ much from the corresponding indicator for a system with micro inverters designed to connect only one PV module, while assessing the reliability within a period equal to the warranty period of a standard inverter (approximately 10 years).

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