Decoupling protection in power generation plants

Check reactive power directional undervoltage protection correctly

Bryan Fleuth B. Eng., Product Manager, KoCoS Messtechnik AG, Korbach, Germany

Due to the steadily increasing number of decentralized power generation plants, plant operators are obliged to install more and more reactive power directional undervoltage protection (Q-V protection). This must be tested according to the guidelines and the functionality must be confirmed in a test report. However, the various test instructions leave a great deal of room for interpretation in some cases, which leads to ambiguities. KoCoS has taken a closer look at the instructions and has come up with solutions for carrying out Q-V protection tests.

The share of renewable energies in Germany's total electricity consumption has become increasingly important over the last 20 years. While renewable energies accounted for 6% of total consumption in 2000, by 2018 it had already reached 38%. By the year 2025, an increase to 40-45% is expected. Most of this will be provided by wind and solar energy [1]. In 2019, Germany was the European leader in wind energy with a total installed capacity of over 53 GW [2]. Due to the capacity of the individual generation plants, they are connected directly to the medium and high voltage grids. Grid operators were required to rethink their system protection and adapt it to the new grid structures. In response to this, the reactive power directional undervoltage protection (Q-V protection) was included in the technical connection conditions. In these guidelines, both the mode of operation and the setting values are largely specified.

Q-V protection for more system stability

Unlike overcurrent time protection or distance protection, Q-V protection is not intended to protect a specific object such as generators or cables. Q-V protection is primarily a system protection which serves to ensure a safe operating state of the power system. Q-V protection is used to disconnect power generating units from the grid, which would amplify the resulting voltage funnel in the event of a system fault in the power grid. This is intended to prevent a complete voltage collapse and increase system stability.

Reactive power monitoring and undervoltage protection

For the following consideration of the function blocks of the Q-V protection, the standard values from the „Specifications for reactive power directional undervoltage protection" are used. The actual parameter values may vary depending on the system and are specified by the grid operator [3].

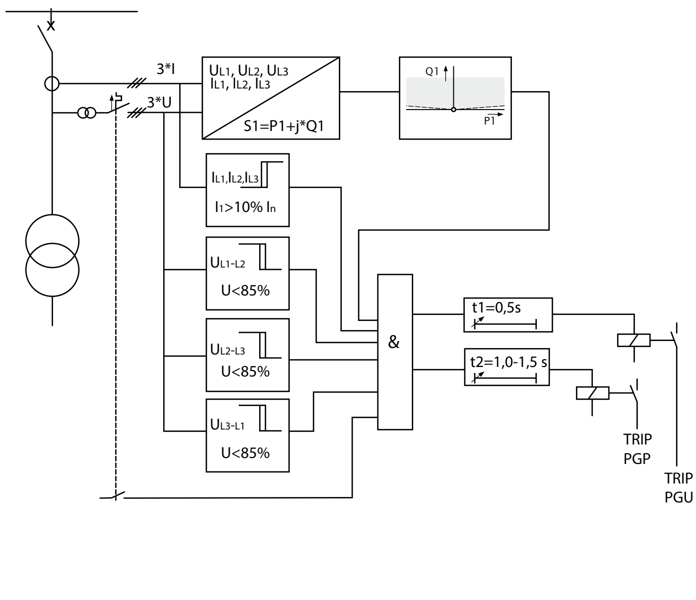

Figure 1: Block diagram of the reactive power directional undervoltage protection [3]

The main component of Q-V protection is the reactive power criterion. This function block monitors whether the power generating plant (PGP) takes inductive reactive power from the grid and thus does not contribute to voltage reinforcement in the event of a fault. The consumer counting system is used to describe the power level. For the reactive power criterion, two variants are available for determining the tripping area. In order to prevent an overfunction of the reactive power detection, the characteristic curve is inclined by the angle φ and linked to a minimum current I_1 in variant 1. Variant 2 is realized by a pure reactive power threshold (straight line parallel to the active power axis). A minimum current criterion can also be integrated here, but this is not absolutely necessary [3].

For the following explanations and examples, reactive power monitoring according to Variant 1 with a tilt angle of $\varphi = 3°$ and a minimum current $I_1 = 0.10$ In is assumed. In addition, the reactive power monitoring is linked to an undervoltage protection. Here it must be noted that the monitoring of the individual phase voltages is not OR-linked as with pure undervoltage protection but AND-linked. All three phase-to-phase voltages must therefore fall below the limit value of $U_{LL<Q\text{-}V} = 0.85\ U_n$. If both, the reactive power and the phase-to-phase voltages, are within the tripping range, two time stages are started. After t1 = 0.5 s, the power generating units (PGU) are disconnected from the grid at the generator circuit breaker. If these do not react, the entire PGP is disconnected from the grid after the second time stage t2 = 1.5 s.

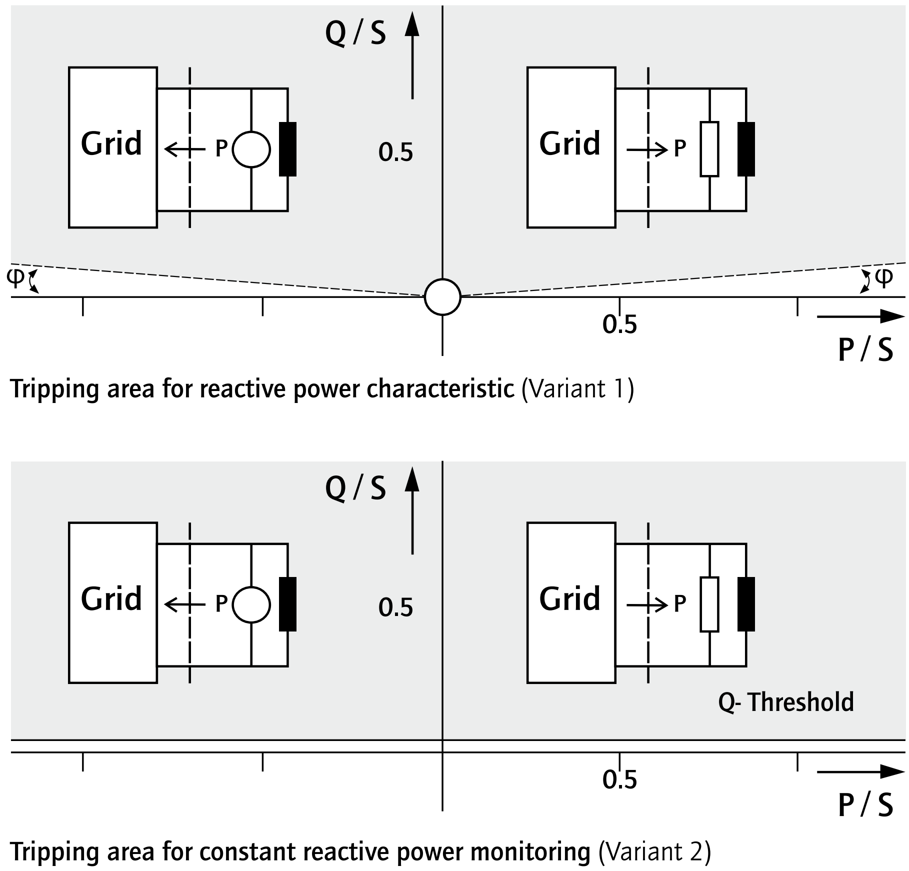

Figure 2: Variants for the tripping range of the reactive power direction detection

Implement test instructions correctly

Due to the steadily increasing number of decentralized power generation plants, which must be equipped with Q-V protection as a mandatory requirement under various directives, the demand for protection tests has also risen in recent years. Since the plant operators cannot carry out these tests themselves in most cases, a new, constantly growing business area for technical services was created. Due to the limited availability of protection testers, companies that construct power generation plants are now also dealing with protection testing in order to be able to hand over the plant, including the commissioning test, to the operator in due time. For these companies, a test instruction is indispensable, since protection testing is not part of their core business.

However, since the guidelines do not specify detailed test instructions in addition to the description of the protective function, specially prepared instructions have been published by various bodies. At first glance, these are largely identical and contain the required test steps. On closer inspection, however, they leave a certain amount of room for interpretation, with the result that the test results are sometimes unclear or misinterpreted.

Voltage test

Usually the voltage test is the first step. Current and angle are set so that the trip criterion would be fulfilled. If the voltage then drops symmetrically, the pick-up or tripping signal should be present at 0.85 U_n and the drop-off test can be initiated. This point is clearly and unambiguously described in all instructions. In the next step, the AND link of the undervoltage monitoring must be checked. For this purpose, it is often stated that the voltages must be reduced to 0 V in single and two-phase operation and that no tripping may occur in these cases. Since test systems usually work with phase-to-neutral voltages, the simplest interpretation would be to first lower the phase-to-neutral voltages individually and then two phase-to-neutral voltages simultaneously to 0 V.

However, when considering this, it must be noted that the Q-V protection monitors the phase-to-phase voltages as described above. If the single-phase voltage drop is checked first, the undervoltage criterion is not met, since one phase-to-phase voltage remains at the nominal voltage. For the two-phase voltage drop, two phase-to-neutral voltages would now be reduced analogously from the nominal voltage to 0 V. In this case, all 3 phase-to-phase voltages would drop below 0.85 Un. One phase-to-phase voltage would have 0 V and the other two would drop to the value of the phase-to-neutral voltage. In this state, the undervoltage criterion would be met and the protection would trip. However, since tripping must not take place for a successful test, the test could be erroneously evaluated as failed. However, if a real two-phase voltage fault is simulated, in which the phase-to-neutral voltages converge, no tripping would take place, since two phase-to-phase voltages >0.85 U_n remain, while one falls to 0 V [4].

Tripping angle

Following the voltage test, the tripping angle should be checked. For this purpose, the voltage and current values must reliably meet the tripping criterion. For this purpose, all voltages are set to 0.82 U_n and the currents to 0.2 I_n, for example. As described above, the consumer counting system is used and the tripping range is in quadrants 1 and 2.

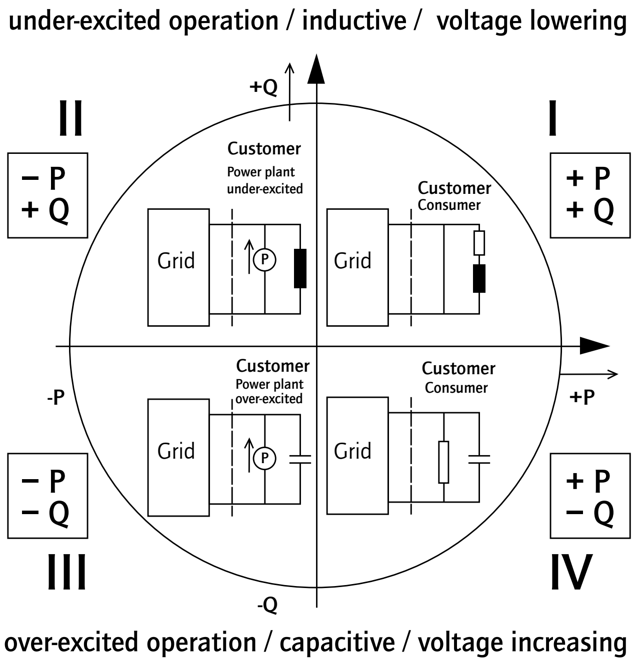

Figure 3: Description of the power level using the consumer counting system [5]

In order to check the tripping angle, the pointer of the apparent power S would now have to be turned step by step from the third to the second quadrant or from the fourth to the first quadrant. On the one hand, very complex instructions can be found for this test, the description of which can sometimes lead to confusion. On the other hand, there are simply described instructions, but these do not lead to the desired result. These instructions are based on changing the angle of the currents in relation to the voltage angles. However, in some cases the relationship with the power angle is not correctly taken into account, taking into account the earthing point of the current transformers.

Release current

In the final test of the release current, hardly any ambiguities or scope for interpretation can be identified. In principle, the test is carried out similar to the symmetrical voltage reduction. However, in this case the voltage is placed in the safe tripping area and the current is increased symmetrically step by step until excitation/tripping occurs.

Create unique test plans

Basically, the test instructions for Q-V protection are structured identically. However, as shown above, there may be some open questions. Therefore, a clear test plan should be drawn up which leaves no room for interpretation.

For the voltage test, the reactive power reference (or angle) and the currents must be constantly within the safe tripping area. Both criteria are met if the currents are set with an amount of $I > 0.2\ I_n$ and the angles to the voltages are set so that the power vector has an angle of 90°. In the power plane this would correspond to pure reactive power consumption without active power. Subsequently, the voltages are reduced symmetrically starting from the nominal voltage, whereby the step length should be at least 2 s. In this way, excitation value and tripping time can be checked. After tripping, the voltages are increased again symmetrically to determine the drop-off value. In the next step, the AND connection of the voltages is checked. First, the individual phase-to-neutral voltages are reduced to 0 V in single phase, whereby no tripping may occur. Finally, the individual phase-to-phase voltages must be lowered to 0 V, taking into account the correct physical behavior. Again, no tripping must occur.

To test the tripping angle, set the voltages to $U < 0.82\ U_n$ and the currents to $I > 0.2\ I_n$, as for the voltage test. As described above, the angles of the currents must now be changed so that the angle of the apparent power rotates from the third to the second quadrant and from the fourth to the first quadrant. Here too, a step length of at least 2 s must be selected and a drop-off test must be carried out. For the test of the release current, the voltage must again be set to $U < 0.82\ U_n$ and the angle of the current must be set to a safe tripping such as a pure reactive power consumption. For the test, the current is increased stepwise starting with 0 A with a step length of 2 s up to the starting value and the tripping time is recorded.

All results shall be recorded in a test report. This report must be submitted by the system operator upon request of the grid operator. The test steps described refer only to testing the Q-V protective function. Further tests such as tripping with circuit breaker action must be included in the test plan if necessary.

Automatic testing with ARTES RC3 and Smartphone

KoCoS Messtechnik AG has been developing and producing systems for testing all types of protective relays for more than 20 years. The ARTES RC3 is a test system which has been optimized for testing decoupling protection. It has been reduced to the minimum necessary for this purpose and equipped with a 5" control unit integrated into a robust housing.

Figure 4:
ARTES RC3 - Automatic relay test system, optimized for testing the decoupling protection

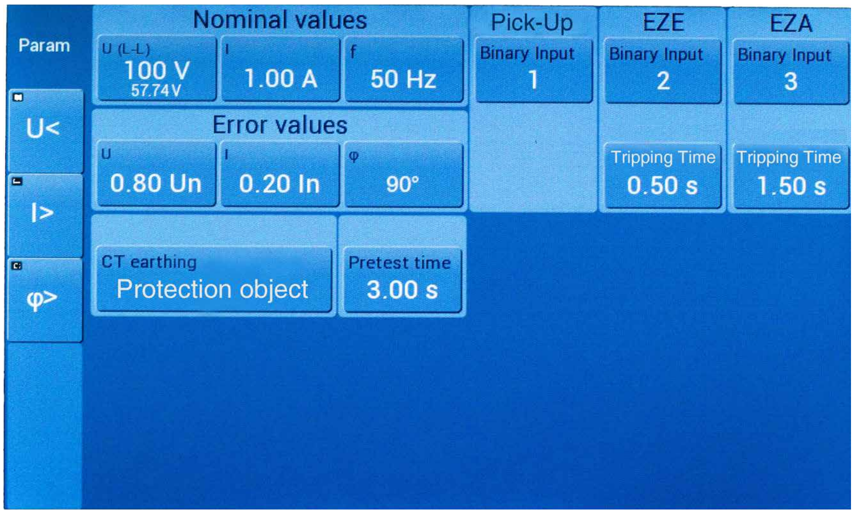

Figure 5: Q-V protection test with ARTES RC3. The required parameters for nominal values and error values as well as the configuration are set directly via the control unit.

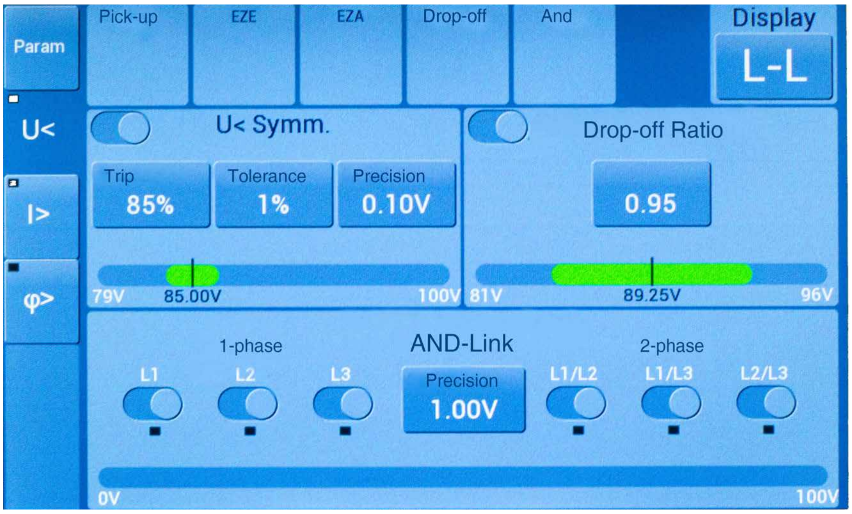

Figure 6: ARTES test monitor for voltage testing. The individual test steps are selected and then automatically executed and evaluated.

Due to the intended application under rough conditions, a special module for testing the Q-V protection was integrated into the internal control unit. This enables the complete testing of the Q-V protection including logging even without a PC. For the test, specifications for the setting values and the desired error conditions only have to be made once.

Based on this, the activated individual tests are executed automatically. The examiner uses an app on his smartphone to manage the results. By means of a scan function, the results are transferred, combined to a predefined test report and stored in a database. This way the report can be sent directly or synchronized later with the database of the test software on the PC.

The most important prerequisite for a resilient Q-V test remains a sound knowledge of grid protection. This is the only way to correctly interpret the various test instructions. However, implementation in practice can be supported by modern test technology with preset parameterization as well as automatic execution, evaluation and logging. After all, both service providers and operators are equally responsible here.

Literature:

[1] „Bundesministerium für Wirtschaft und Energie," [Online]. Available: https://www.bmwi.de/Redaktion/DE/Dossier/erneuerbare-energien.html. [Access on 03 April 2020].

[2] „Bundesverband WindEnergie," [Online]. Available: https://www.wind-energie.de/themen/zahlen-und-fakten/deutschland/. [Access on 03 April 2020].

[3] FNN-Forum Netztechnik/Netzbetrieb im VDE, „Lastenheft Blindleistungsrichtungs-Unterspannungsschutz (Q-U-Schutz)," Berlin, 2010.

[4] BDEW-Bundesverband für Energie- und Wasserwirtschaft e.V., „Technische Richtlinie „Erzeugungsanlagen am Mittelspannungsnetz"," Berlin, 2008.

Curriculum Vitae

In cooperation with ABB Automation GmbH, Bryan Fleuth completed a dual course of study in electrical engineering at the DHBW-Mannheim (Baden-Wuerttemberg Cooperative State University), which he completed as a Bachelor of Engineering (B. Eng.). In March 2018, Mr. Fleuth began his career at KoCoS Messtechnik AG and is now Product Manager for Protection Relay Test Systems. He is the contact person for distributors and customers worldwide and provides them with competent support based on his product and application knowledge.

Bryan Fleuth B. Eng., Product Manager,
KoCoS Messtechnik AG, Korbach, Germany

KoCoS
A FRIEND OF ENERGY

KoCoS Messtechnik AG
Südring 42
34497 Korbach, Germany
Phone +49 5631 9596-40
info@kocos.com
www.kocos.com