Everything under control

SIPROTEC 7UT635 differential protection for Allgäuer Überlandwerke

■ The company

Power for Allgäu – Allgäuer Überlandwerke GmbH (AÜW) is committed to it, supplying electricity to more than 80,000 customers.
AÜW considers itself to be an energy service provider, because, in addition to simple delivery, they offer customers a variety of services related to power supply.

The starting situation

Transformers with phase-angle regulation and regulation in quadrature are used to regulate the voltage and power flow in power supply systems. These are special transformers. Until now, it has not been possible to use 7UT5 and 7UT6 differential protection unless the protection relay was configured to be relatively insensitive. The measurement algorithm is designed for a vector group compensation of N*300 (N=0,1 to 11) and is preset to vector group 0 as per the transformer's rating plate. The problem is that the transformer with phase-angle regulation generates an angular shift that deviates from zero.

The transformer with phase-angle regulation (see Fig. 2) comprises a tap changer on side 1 and is responsible for in-phase control.

A sensitive configuration guarantees protection

Quadrature control is performed on side 2 where an out-of-phase voltage is added to the longitudinal voltage of the transformer winding. The overview in Fig. 2 shows, for example, that a phase L3 or L2 transverse voltage is added to Phase L1, depending on the tap position of the quadrature transformer. The amount of transverse voltage can be controlled, resulting in an angular shift between overvoltage and undervoltage that is no longer 0 degrees but may be as high as max. ±35°. Because control can be in a positive or negative direction as a function of the power flow, significant differential currents already result under normal conditions. In the event of a short-circuit, a fault outside the protected zone can result in an unwanted operation of the protection relay – even if the relay is configured with a rated current approx. four times less sensitive than a normal differential protection relay.

LSP2726.tif

Fig. 1 Transformer with phase-angle regulation

In Fig. 3, a fault of this type is shown in the protection relay's tripping characteristic and, with the selected setting, results in unwanted protection operation. Configuring the protection relay with an even less sensitive setting would have compromised the entire concept of differential protection.

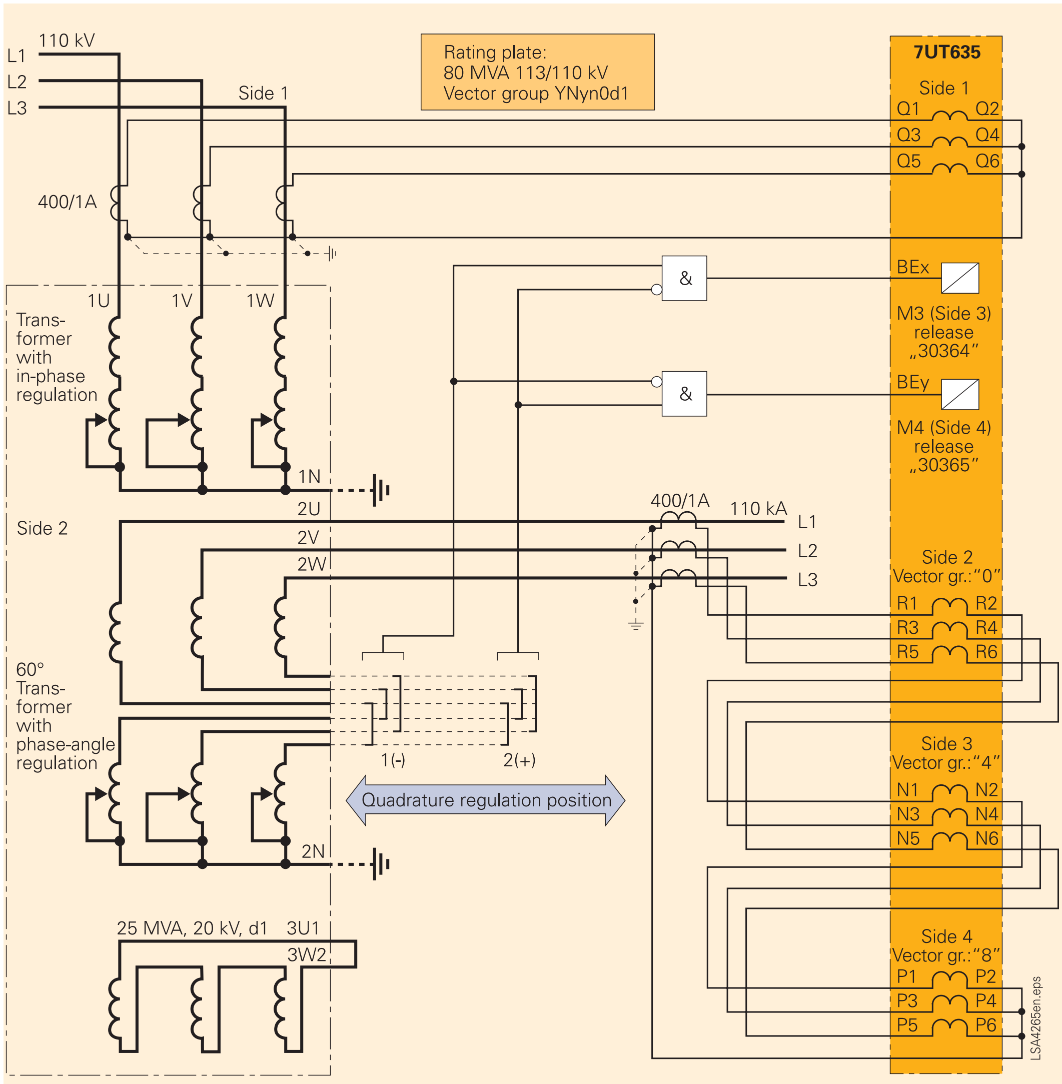


Fig. 2 Transformer with phase-angle regulation connected to 7UT635

The concept

For the purpose of analyzing the problem, the transformer with phase-angle regulation with its extensive control range was mathematically simulated in the computer. The mathematical model makes it possible to calculate the currents on side 1 and side 2 of the transformer. The 7UT635 protection relay measures these currents (connection as per Fig. 2). The vector group adaptation and differential protection algorithm are also mapped on the computer, with the result that the currents calculated are used directly as input variables for the protection system simulation. With the aid of a test set, the currents calculated can also be output to a 7UT6 protection relay and fed into the protection relay at side 1 and side 2 via analog amplifiers. This systematic method serves to map transformer and protection system behavior.

In addition, the results of the simulation could be compared to faults that the customer has already recorded by means of fault recorders, thus providing another opportunity to test the model.

The solution was intended to operate without any modification of the measurement method or of the protection relay's vector group compensation, and to be adapted to the existing device.

Compensation by parameterization

The task was to compensate for the large phase angle rotation of the transformer with phase-angle regulation by means of circuitry and parameterization, while taking into account the positive and negative control range.

For this purpose, the current measured on side 2 was fed to two additional input windings in the device. Fig. 2 shows the interfacing. The vector group and data for these windings are now configured so that the behavior of the phase-angle transformer can be largely compensated in the device.

SIPROTEC 7UT63 selective short-circuit protection

The protection relay selected was the 7UT635 offering 3 additional windings, 2 of which are used. The transformer with phase-angle regulation is parameterized like a four-winding transformer. Side 3 measures the current for the positive control range and side 4 for the negative control range. For the 7UT613/7UT635, the current measurement inputs for the sides can be connected and disconnected via a binary input. This product feature can be used here to great advantage.

In accordance with the basic solution approach, protection relay parameterization was now developed for the customer's transformer and transferred to the device using DIGSI. The configuration data appears in Fig. 4.

■ The special advantages

Optimized for phase shifting

Parameterization for the protection relay was optimized for a ±17.5° phase shift by the phase-angle transformer. For this angle, the longitudinal voltage to be parameterized for winding 2 and the transverse voltage to be parameterized for winding 3/4 can be calculated from the transformer data to yield a differential current equal to zero. The vector group for winding 3/4 is set to 4/8 and optimally emulates the quadrature control response for the operating point selected. Superimposing the currents measured at the windings yields a 17.5° phase shift for the operating point selected. Angles that deviate from 17.5 degrees result in a small differential current that must fall below the pickup value.

Testing the protection

The sensitivity of the protection was configured so that it would no longer be possible for spurious pickup to occur at a ±35° phase shift, corresponding to a mismatch of 17.5° with the operating point. This is achieved with a setting of 0.6 I_N, a value that still provides adequate security.
The result is twice the sensitivity of a conventional parameterization. The performance of the protection relay can be tested by outputting various operating and fault scenarios; all important data can be read from the fault record. Fig. 5 shows the optimal response to a fault in the tripping characteristic, which was still resulting in unwanted operation in Fig. 2. Now, high stability with external faults has been achieved even with a sensitive setting of the differential protection relay.

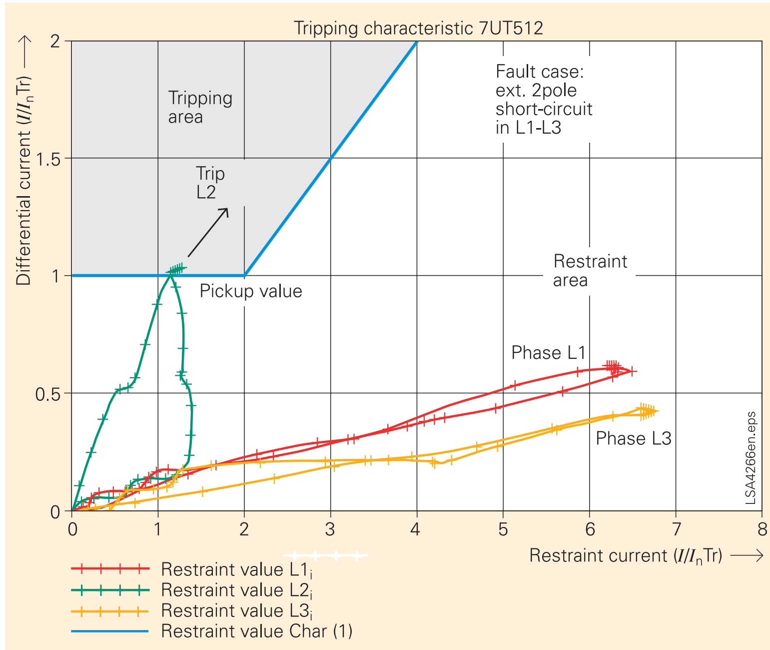
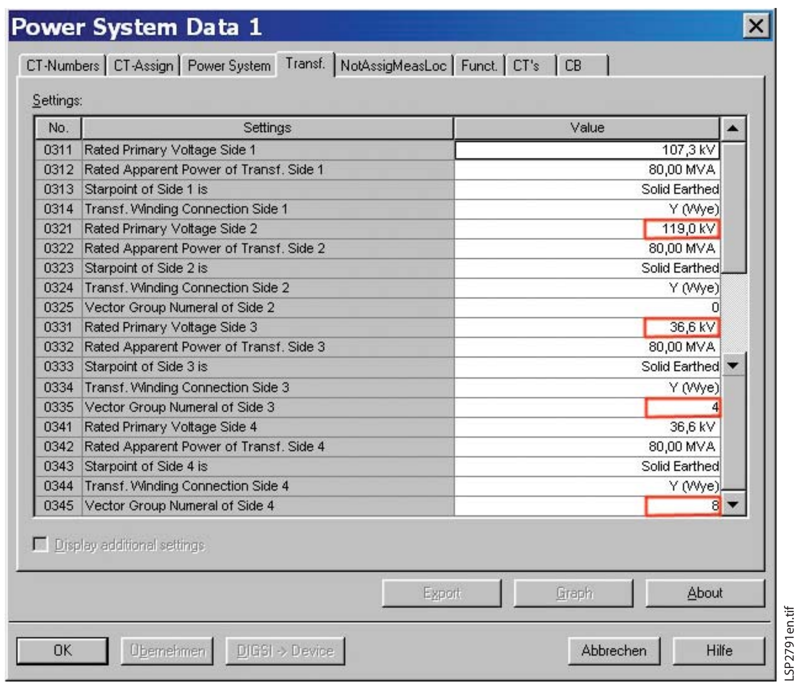


Fig. 3 Tripping characteristic without compensation of phase regulation



No.	Settings	Value
0311	Rated Primary Voltage Side 1	107,3 kV
0312	Rated Apparent Power of Transf. Side 1	80,00 MVA
0313	Starpoint of Side 1 is	Solid Earthed
0314	Transf. Winding Connection Side 1	Y (Wye)
0321	Rated Primary Voltage Side 2	119,0 kV
0322	Rated Apparent Power of Transf. Side 2	80,00 MVA
0323	Starpoint of Side 2 is	Solid Earthed
0324	Transf. Winding Connection Side 2	Y (Wye)
0325	Vector Group Numeral of Side 2	0
0331	Rated Primary Voltage Side 3	36,6 kV
0332	Rated Apparent Power of Transf. Side 3	80,00 MVA
0333	Starpoint of Side 3 is	Solid Earthed
0334	Transf. Winding Connection Side 3	Y (Wye)
0335	Vector Group Numeral of Side 3	4
0341	Rated Primary Voltage Side 4	36,6 kV
0342	Rated Apparent Power of Transf. Side 4	80,00 MVA
0343	Starpoint of Side 4 is	Solid Earthed
0344	Transf. Winding Connection Side 4	Y (Wye)
0345	Vector Group Numeral of Side 4	8

Fig. 4 Parameterizing of windings 1 to 3 (setting for winding 3 are valid for winding 4, too)

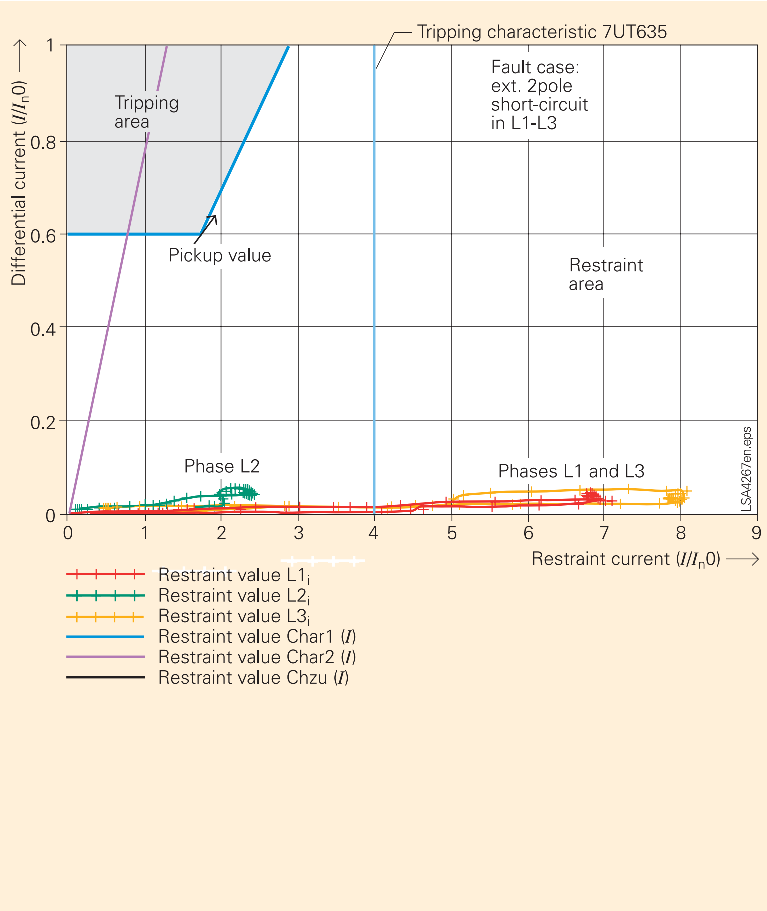


Fig. 5 Tripping characteristic with compensation of phase shifting

Control via binary inputs

Connection and disconnection of the measurement inputs is controlled via binary inputs. Fig. 6 shows the DIGSI 4 configuration matrix with the signals releasing the measuring points. In a positive control range (>2(+)) from 0 to 35°, measurement input 4 is released; in a negative control range (< 1(-)) from 0 to -35°, measurement input 3 is released. The transfer is by means of signals from the phase-angle transformer tap changer when the power flow changes from a positive direction (position 2+) to a negative direction (position 1-). In the range from (2+) to (1-), both inputs are blocked and the differential protection operates as a two-winding transformer with vector group 0.

Conclusion:

An elegant solution was found by using the SIPROTEC 7UT635 to compensate the large phase-angle rotation of the transformer with phase-angle regulation by means of circuitry and parameterization. A sgnificantly more sensitive setting was selected for the differential protection thus providing a reliable sensitive protection for the complete control range. This advantage can also be applied to all the other transformers with regulation in quadrature. The only requirement is that parameterization be adapted to the object to be protected..

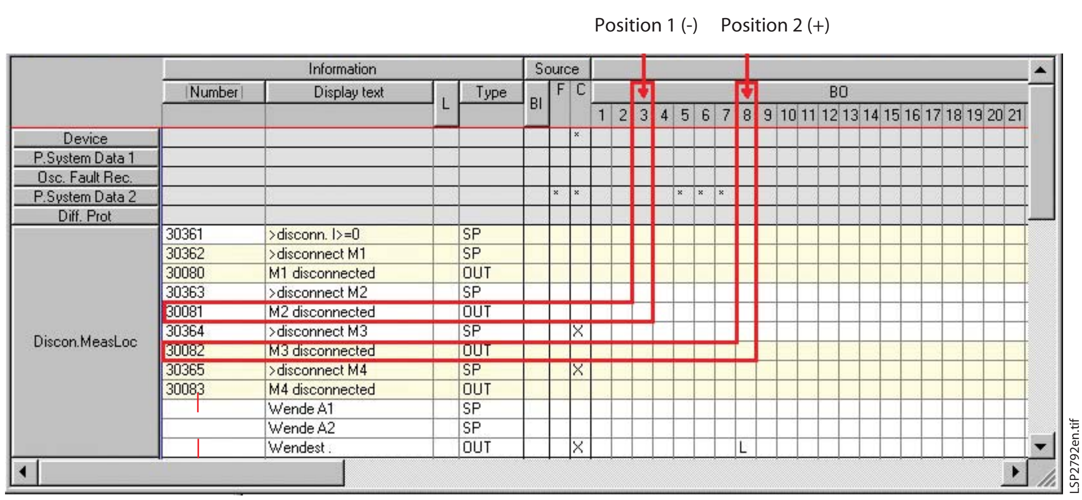


Fig. 6 Control of measuring elements via binary inputs (marshalling in DIGSI configuration matrix)