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Practical Test of Power Swing Blocking Relay

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***Abstract*— Distance relays are the main protection that used to protection of transmission lines against electrical faults. According to the feature of this relays, which detect faults by utilizing the impedance of the line, they are susceptible to maloperation during power swing, which cause significant changes in the impedance of the line. The function of the power swing blocking is to detect impedance swings and block the distance relay to prevent its operation when it occurs. In this paper, stable and unstable power swings in transmission lines and their features are explained first. Then, by using the simulation part of AMPro software, the power swing parameters are defined and the AMT205 test set is used to perform the tests. The results show that the relay under test detects power swing properly in both types.**

Power Swing Blocking, Distance Relay, Transmission Lines, Power System Protection, relay testing (key words)

I. Introduction

Transmission lines are one of the most important parts of the power system; if a fault occurs in a transmission line, the power system equipment is severely damaged and may cause blackouts in some areas. Therefore, the protection of transmission lines is an important issue in the operation of electric power systems [1]. The distance relay is the main protection of the transmission lines. These relays are influenced by different internal and external factors, compromising its performance [2]. When a sudden disturbance occurs, such as a short circuit, the outage of a parallel line, a sudden load increase, etc., the impedance seen by distance relays swings and goes into the zone of the distance relay and cause malfunction. To prevent this, power swing blocking function is used to detect the power swing and to block tripping of the distance relays [3]. These relays need to be accurately tested to ensure their proper functioning and response to various fault scenarios. Because of these reasons, relay manufacturers and utility engineers require test methods that are more rigorous than the static test presently used. Hidden problems are a large part of the relays problems that cannot be identified in the normal condition of the power system [4]. The testing and verification of protection devices and arrangements introduces a number of issues. This happens because the main function of protection devices is related to operation under fault conditions so these devices cannot be tested under normal operating conditions. The testing and verification of relay protection devices can be divided into four groups [5]:

- Routine factory production tests
- Type tests
- Commissioning tests
- Occasional maintenance tests

In [6] and [7], the test procedure of the synchronization relay and var control relay (VCR) is discussed respectively. Reference [8] provides a comprehensive overview of the scenarios that give rise to power swings, how protection relays response, and how the implementation of protection algorithms by different manufacturers can cause similar relays functions to react in different ways.

In this paper, at first a protective relay from Vebko brand (AMR) has been investigated and then various cases of power swing have been performed using the Vebko AMT205 test set to check the functionality of the relay.

II. Power Swing

When a fault or disturbance occurs in a power system, the generators respond by adjusting their output to compensate for the imbalance. This adjustment can lead to a temporary increase or decrease in power flow along transmission lines, resulting in a swing-like motion of power throughout the network.

Power swings are categorized into stable and unstable swings:

Stable Power Swing

A stable power swing occurs when a disturbance, like a fault or sudden change in load, causes temporary fluctuations in the power flow of a transmission line.

Characteristics:

- These swings are self-limiting and usually do not result in any loss of synchronism among generators.
- The power system stabilizes back to its original state once the disturbance is resolved.
- Typically, the power swings are controlled and damped by various mechanisms like governors, voltage regulators, or power system stabilizers.

Outcome: The system remains in synchronization, and the power flows stabilize without causing any significant instability.

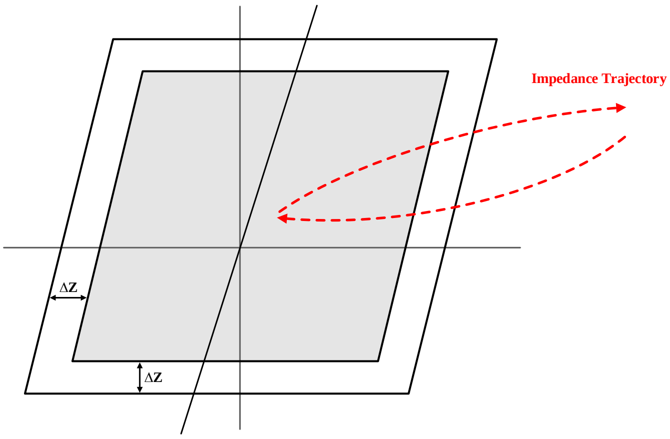

Figure 1. Impedance trajectory of stable power swing

Unstable Power Swing

An unstable power swing occurs when the system faces a severe disturbance, causing excessive oscillations that lead to a loss of synchronism among generators or groups of generators.

Characteristics:

- These swings can lead to a significant loss of synchronization between generators, resulting in instability within the power system.
- The oscillations may persist and magnify, causing a cascading effect, leading to system collapse if not controlled or corrected.
- The system fails to regain stability on its own and may require corrective actions or interventions to prevent widespread outages.

Outcome: Loss of synchronization can lead to blackout or severe disruption within the power system, requiring immediate corrective measures to restore stability.

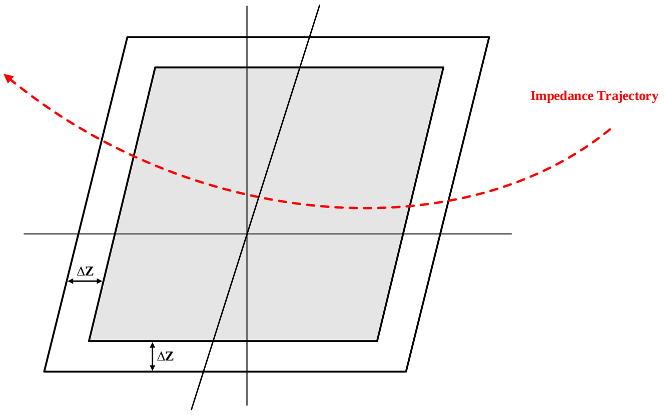

Figure 2. Impedance trajectory of unstable power swing

Power Swing Detection

In order to detect the power swing, the rate of change will be adjusted to the impedance phasor. In order to warrant all functions of the power-swing detection are stable and secure, without the risk of overfunction during a short circuit, the following measurement criteria are used [9]:

- Trajectory monotony:

During a power swing, the measured impedance indicates a directional path of movement. This path occurs precisely if within the measurement window one of the components ΔR and ΔX at the most indicates a change of directions. As a rule, if a short circuit occurs, it causes a directional change in ΔR as well as in ΔX within the measured value window.

- Trajectory continuity:

The spacing of 2 consecutive impedance values will clearly indicate a change of ΔR or ΔX during a power swing. If a short circuit occurs, the impedance vector skips to the short-circuit impedance and remains motionless.

- Trajectory uniformity:

During a power swing the ratio between 2 consecutive changes of ΔR or ΔX do not overshoot a threshold. As a rule, if a short circuit occurs, it will cause an erratic movement since the impedance phasor abruptly skips from load impedance to short-circuit impedance.

III. The Test Connection

In order to accomplish connection of the relay under test[i] and the AMT205 test set, first the voltage outputs VA1, VA2 and VA3 of the tester are connected to the voltage inputs of the relay, then the current outputs IA1, IA2 and IA3 of the tester are connected to the current inputs of the relay. Also, the relay binary outputs are connected to the binary inputs of the tester. Figure 3. and Figure 4. show the wiring of the relay and tester devices, respectively.

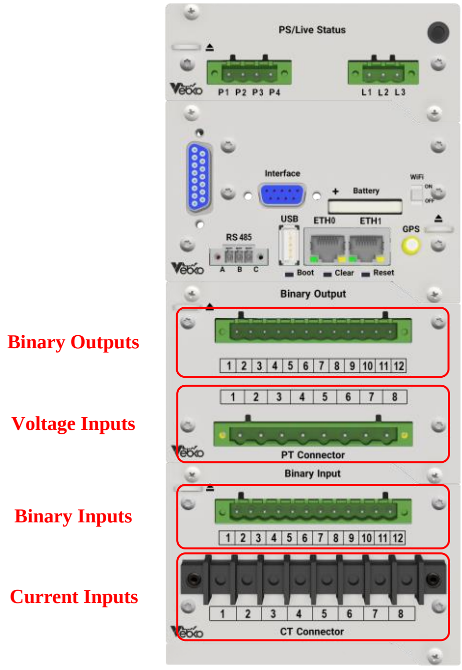

Figure 3. Connection of the relay device

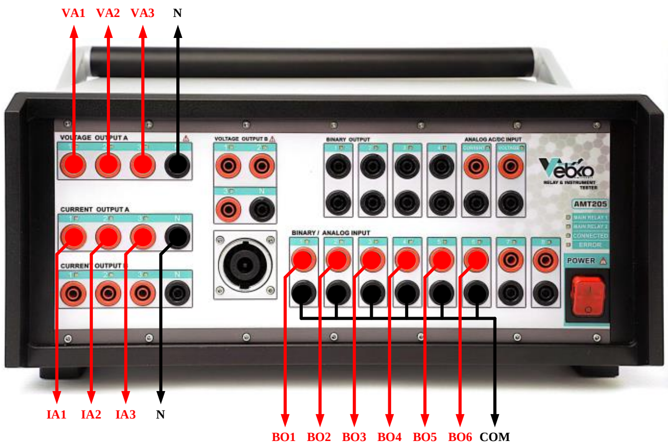

Figure 4. Connection of the tester device

IV. The Relay Test

AMPro Software

A simulation module has been designed in AMPro software, which provides the capability to model a network, consisting of components such as sources, transmission lines, transformers, compensators, and circuit breakers. By using the tools available in this module, various test cases such as faults and power swings can be simulated on the network.

To access this module, the state type must be set to transient, and the simulation tab will be added by ticking the simulation checkbox. Parameters of this module is shown in Figure 5.

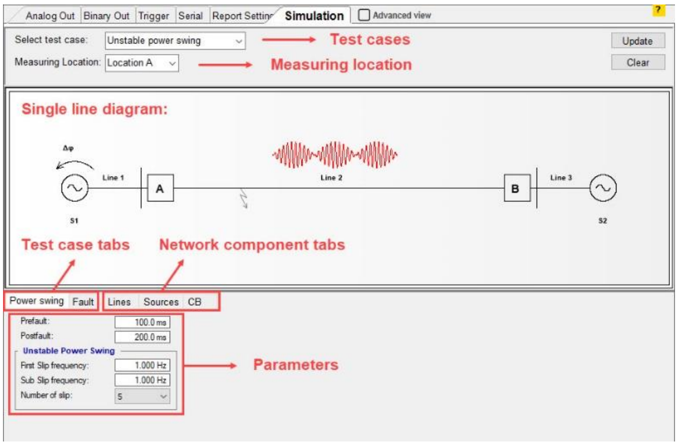

Figure 5. Simulation module in AMPro software

TABLE I. PARAMETERS OF SIMULATION MODULE

Parameter	Description
Prefault	The fault occurs after the prefault time has elapsed
Postfault	The postfault time starts after the fault is applied
First Slip frequency	The frequency of the first difference between the two generators
Sub Slip frequency	The frequency of sub difference between the two generators
Number of slips	Number of swing repetition

Stable Power Swing Testing – Static Test

In this test, stable power swing is tested with a static manner according to following parameters:

TABLE II. PARAMETERS OF STABLE POWER SWING STATIC TEST

Parameter	Setting
Prefault	100 ms
Postfault	200 ms
Slip angle	150 degrees
Slip time	1 s

The signals derived from TABLE II. are depicted in Figure 6. These signals are injected to the relay under test via AMT205 test set to simulate the impedance trajectory of a stable power swing. Power swings are 3-phase symmetrical events [9]. So, a certain symmetry of the measurands is assumed. When the power swing blocking detects a power swing, issues a signal with the names of "Block Zones" (for each individual phase) that causes blocking of the distance relay. The relay operation is monitored by detecting pickup and trip signals of the distance and Block Zones 1, 2, 3 signals of power swing blocking functions.

By Injecting current and voltage signals, the impedance seen by the relay moves from the load impedance to the center of the impedance plane. The relay should identify this movement as a power swing. In stable power swing the impedance trajectory enters into the distance zones from right side and leaves from the same side but in unstable power swing the impedance trajectory enters into the distance zones from right side and leaves from the other side of the zones.

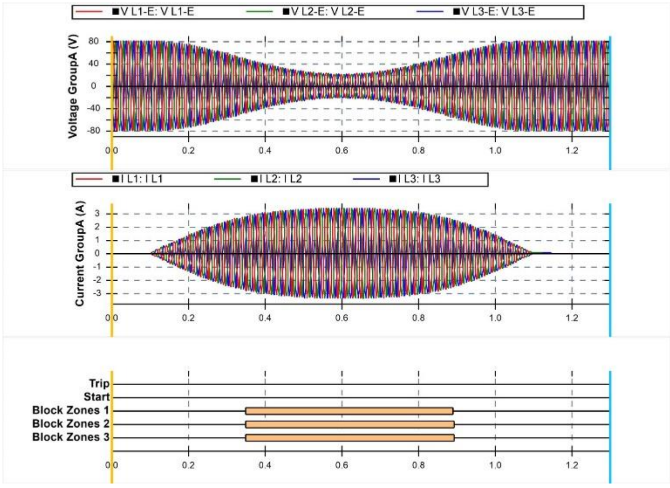

Figure 6. Signals of stable power swing static test

The relay has successfully detected power swing and issued related signals. Additionally, the distance protection function did not operate. The impedance trajectory of stable power swing static testing is shown in Figure 7.

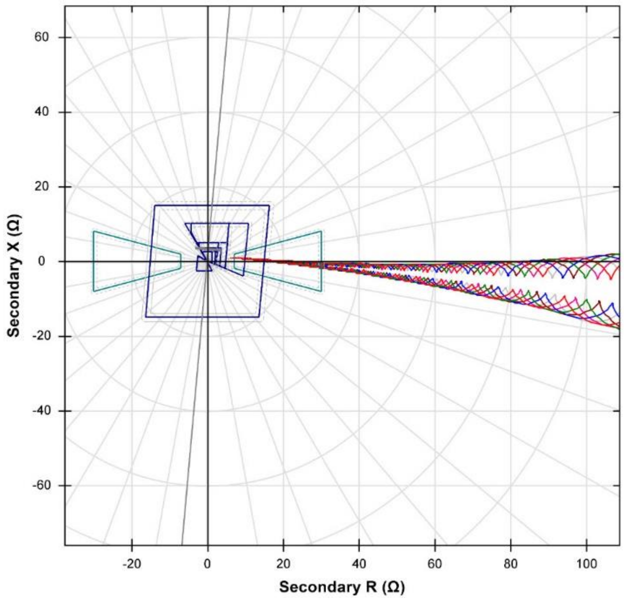

Figure 7. Impedance trajectory of stable power swing static test

Stable Power Swing Testing – Dynamic Test

In this test, stable power swing is tested with a dynamic manner according to following parameters:

TABLE III. PARAMETERS OF STABLE POWER SWING DYNAMIC TEST

Parameter	Setting
Prefault	100 ms
Postfault	200 ms
Slip angle	90 degrees
Slip time	1 s
Time constant	1 s
Slip frequency	2 Hz

The signals derived from TABLE III. are depicted in Figure 8. These signals are injected to the relay under test to simulate the impedance trajectory of a stable power swing. The relay operation is monitored by detecting output signals of the relay.

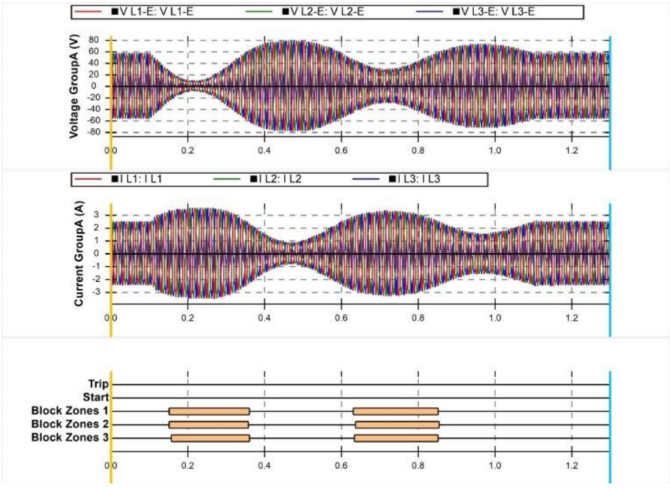

Figure 8. Signals of stable power swing dynamic test

The relay has successfully detected power swing and issued related signals. Additionally, the distance protection function did not operate. The impedance trajectory of stable power swing dynamic testing is shown in Figure 9.

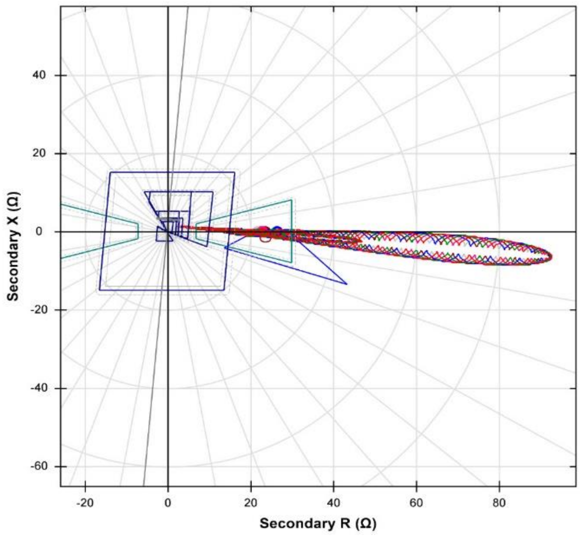

Figure 9. Impedance trajectory of stable power swing dynamic test

Unstable Power Swing Testing

In this test, an unstable power swing is tested according to following parameters:

TABLE IV. PARAMETERS OF UNSTABLE POWER SWING TEST

Parameter	Setting
Prefault	100 ms
Postfault	200 ms
First Slip frequency	1 Hz
Sub Slip frequency	2 Hz
Number of slips	5

The signals derived from TABLE IV. are depicted in Figure 10. These signals are injected to the relay under test to simulate the impedance trajectory of a stable power swing. The relay operation is monitored by detecting output signals of the relay.

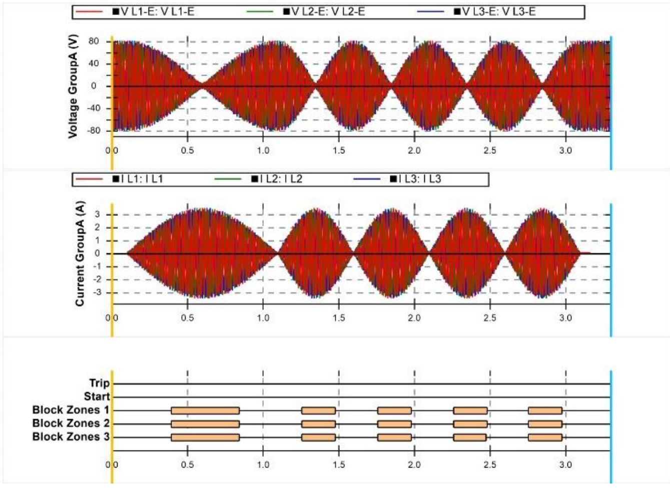

Figure 10. Signals of unstable power swing test

The relay has successfully detected power swing and issued related signals. Additionally, the distance protection function did not operate. The impedance trajectory of unstable power swing testing is shown in Figure 11.

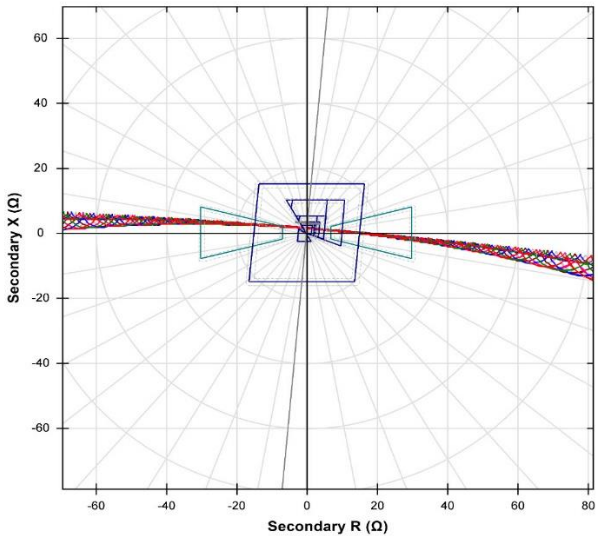

Figure 11. Impedance trajectory of unstable power swing test

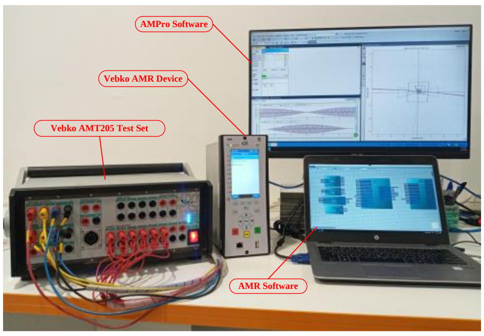

Figure 12. Practical test of power swing blocking relay

V. Test flowchart

Relay testing flowchart is given below.

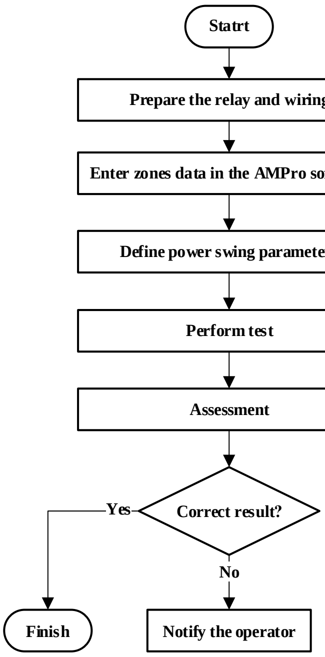

Figure 13. Test flowchart

VI. Conclusion

In this paper, the stable and unstable types of power swing presented and criterions of power swing detection were discussed. In the following, by using simulation module of the AMPro software and AMT205 test set, various tests are implemented and injected to the relay under test. These tests include stable power swing static test, stable power swing dynamic test, and unstable power swing test. Finally, the performance of the relay is checked and it is shown that it passed all the tests successfully.

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[i] AMR