

### **Adaptive Noncommunication Protection for Power Lines BO Scheme 1: The Delayed Operation Approach**

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**Abstract:** This paper proposes a new technique in power line protection, the adaptive noncommunication protection. In this technique, protection relays make operate or restraint decisions, adapting to system and fault conditions, without the need for communication links. Operation without communication links to signal the remote end relay is achieved by the detection and identification of the operation of the circuit breaker at the remote end of the protected line section. An algorithm based on the symmetric components is proposed to detect and identify the balance condition of the system during the fault. The paper is focused on one of the three protection schemes based on the new technique, the delayed operation scheme. Simulation studies carried out for various systems and fault conditions have demonstrated the feasibility of the scheme.

**Keywords:** Adaptive protection, noncommunication protection, BO protection.

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### **Adaptive Noncommunication Protection for Power Lines BO Scheme 2: The Instant Operation Approach**

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**Abstract:** This paper presents the instant operation scheme of the adaptive noncommunication protection technique for power lines. In the technique, protection relays make tripping or reclosure decisions adapting to system and fault conditions without the need for communication links. The noncommunication is achieved by the detection of whether or not the system is in a balanced operation, in order to identify the breaker operation at the remote end of the protected section. In the scheme, the distance relay will trip instantly when a fault is detected outside its zone 1 but within its zone 2 reach. Subsequently it detects whether the fault is on the protected section or not, and recloses when a fault is cleared from the protected line section. Simulation studies with responses to various system and fault conditions have shown that the technique is able to give fast and correct response without the need for a communication link.

**Keywords:** Adaptive protection, noncommunication protection, adaptive reclosure, optimal reclosure, BO protection.

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### **Adaptive Noncommunication Protection for Power Lines BO Scheme 3: The Accelerated Operation Approach**

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**Abstract:** This paper presents the accelerated operation scheme of the adaptive noncommunication protection technique for power lines with complex configurations, such as multi-end feeder and ring main. In the scheme, the overcurrent directional relays are arranged in two operating modes, the fixed time operation and accelerated operation. The relays with faster operating time in the conventional time grading coordination remain unchanged. The new technique is employed to enable accelerated operation to be achieved for the relays that are in the positions for which slow operating time is set when using conventional time grading technique. For a fault occurring on the protected system, the relays of fixed time operation mode will operate at the preset time for the fault within its protected direction. The relays that are programmed to use accelerated operation mode will determine whether a

fault is on the protected section or not by using the BO technique, that is, to detect the circuit breaker operation by determining whether the line section is in a balanced operation condition or not. The relay makes accelerated tripping decisions for a fault on its protected section. Simulation studies of the responses to various system and fault conditions show that the scheme can significantly increase the speed of the relay responses in the protection of power line systems with complex configurations.

**Keywords:** Adaptive protection, noncommunication protection, overcurrent directional relay, BO protection.

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### **An Agent-Based Current Differential Relay for Use with a Utility Intranet**

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**Abstract:** This paper proposes an agent-based current differential relay for use with a communication network. Agents are software processes capable of searching for information in networks, interacting with pieces of equipment, and performing tasks on behalf of their owners (relays). Results illustrating the performance of the agent-based differential method proposed acting within a communication structure are presented for different traffic conditions. These results also show that a dedicated utility Intranet is a viable and recommended option as a communication media for the proposed scheme.

**Keywords:** Differential protection, relaying, transmission lines, agent technology.

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## **Substations**

### **Grounding Effects of HV and MV Underground Cables Associated with Urban Distribution Substations**

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**Abstract:** The paper derives a model for the evaluation of the performances of composite grounding systems of urban main distribution substations and associated cable networks. The effects of the cables upon the dangerous voltages, transferred potentials, and ground fault current distribution are encompassed, including the conductive and magnetic coupling among grounding system elements as well as the nonlinearity of cables sheaths impedances. An application example is presented and some experimental data.

**Keywords:** Grounding, distribution systems, uncoated metal sheathed cables, dangerous voltages, transferred potentials.

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### **High-Speed Earthing Switch in Gas-Insulated Metal-Enclosed Switchgear**

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**Abstract:** A high-speed earthing switch (HSES) can be permanently installed in the switching apparatus in gas-insulated metal-enclosed switchgear (GIS). A new spring-drive driven HSES has been developed and tested in one-phase and three-phase synthetic test circuits. The HSES rated voltages, 245 kV and 300 kV, enabled closing

(making) operation on the peak value of short-circuit current of 100 kA two times without maintenance, was used. This article presents the main task of HSES at application in GIS, design characteristics, and two different test procedures. Wide searching throughout standards was performed in order to define the real status of this apparatus.

**Keywords:** High voltage, gas-insulated metal-enclosed switchgear, earthing, high-speed earthing switch, making current test.

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## Surge Protective Devices

### An Improvement for the Selection of Surge Arresters Based on the Evaluation of the Failure Probability

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**Abstract:** An improvement on the typical selection procedure of arresters is presented. The analysis shows that the risk of failure of an arrester depends on several parameters (the striking point, the lightning current waveform, the arrester itself, and the system configuration). Therefore, the selection of the optimal arrester depends on how well its stresses can be estimated. After the application of the typical selection procedure, the power system simulations are carried out using the electromagnetic transients program (EMTP) for each suitable arrester. From these results the failure probability of each arrester is calculated, which permits the optimal selection from several valid arresters by the comparison of their risk of failure.

**Keywords:** Surge arresters, lightning, overhead ground wire, failure probability, energy absorption capability.

**Preprint Order Number:** PE-054PRD (8-2001)

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### Thermodynamic and Mechanical Analysis of Gas Explosions in Underground Vaults

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**Abstract:** An explosion in an underground vault can pose a significant safety problem. The ignition of a combustible gas mixture in a rigid vault can generate pressures that can cause damage and failure to the structure of the vault, including the manhole cover. If combustion of the gas within the vault releases sufficient energy, the manhole cover can be ejected, creating a safety hazard.

This article describes a thermodynamic and mechanical analysis of the explosion process in an underground vault. The mathematical model is formulated into a computer program that can be used as a first-step design tool to modify the existing vault designs so that the explosion hazards can be minimized. The computer model predicts the temperature and pressure rise that results from a gaseous explosion within the vault. The pressure rise calculations are then used to predict the motion of the manhole cover if it is ejected from its normal position. The results of the model can be used to improve the design of the vault and its cover to minimize property damage and personal injury should such an explosion occur.

**Keywords:** Vault fires, vault explosions, vault over-pressurization.

**Preprint Order Number:** PE-325PRD (8-2001)

**Discussion Deadline:** January 2002

## Transformers

### Instability of the Machine-Transposed Cable Under Axial Short-Circuit Forces in Large Power Transformers

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**Abstract:** The axial instability of the winding conductor is one of the principal modes of mechanical failure in large power transformers under axial compressive forces generated by the electromagnetic interaction of the short-circuit current and the radial leakage flux. It is a buckling type of mechanical instability that occurs under compression. Two possible modes of failure in the layer-type coil wound with the continuously transposed cable are identified and analyzed in this paper. The critical design loads leading to instability of the individual strands, as well as of the whole cable, are separately derived. The actual instability threshold of the coil would be the lesser of the two critical loads. For the through-fault integrity of the transformer design, this threshold must be greater than the peak compressive force on the cable under the worst-case short-circuit current.

**Keywords:** Transformer, coil, tilting, instability, mechanical strength, short-circuit force, axial compression.

**Preprint Order Number:** PE-004PRD (8-2001)

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### Online Detection and Location of Low-Level Arcing in Dry-Type Transformers

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**Abstract:** This article describes the development of a microprocessor-based system, based on four different physical phenomena, for reliable and accurate detection and location of arcing in dry-type transformers. The proposed technique was tested for actual arcing, generated on a 15kVA, 230/115 V Y/A transformer enclosed in a 30"x30"x21" metallic enclosure. Some results showing the performance of the detection and location system are presented in the article. The technique can be applied to detect arcing in metal-clad low-voltage/medium-voltage switchgear, drives, GIS (gas insulated switchgear), generator bus-ducts, and other metal-clad electrical apparatus against arcing.

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### Determining Ideal Impulse Generator Settings from a Generator-Transformer Circuit Model

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**Abstract:** Impulse testing of large power transformers is a routine test, which is designed to mimic a lightning strike in service. At the design stage, it is useful to have a detailed circuit model of the transformer in order to simulate the impulse test and to check for possibly damaging voltage stress levels. In our model, which includes capacitive and inductive couplings as well as resistive effects, we apply an ideal full or chopped waveform to the impulsed terminal. In an actual impulse test, it is sometimes difficult to approximate the ideal waveform, particularly the full wave one, and a trial-and-error approach is often taken. Here we describe an approach that couples a circuit model of the impulse generator with a transformer circuit model and show how, from this combination, we can arrive at close to ideal settings for the generator, provided such settings are possible.

**Keywords:** Impulse generator, impulse testing, Marx generator, transformer dielectric tests.

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