Application of Multi-Agent Technology to Fault Diagnosis of Power Distribution Systems

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ABSTRACT

When a fault occurs in a power system, the protective relays detect the fault and trip appropriate circuit breakers, which isolate the affected equipment from the rest of the power system. Fault diagnosis of power systems is the process of identifying faulty components and/or sections by analysing observable symptoms (telemetry messages). As the domain is characterised by dynamic situations, extensive telemetering, complex operations, and distribution of lines and substations over a large geographical area, it is difficult to tackle fault diagnosis problems through the strength and capability of a single intelligent system. This paper describes an experimental multi-agent system developed for and aimed at a computer-supported fault diagnosis in electricity distribution networks. The system is based on a hierarchy of five agents that cooperate with each other to diagnose a fault. A set of detailed case studies is presented, and the results obtained suggest that an agent-based approach is very efficient and has a good potential for real-time application.

Keywords: agents; case study; electricity distribution networks; expert systems; fault diagnosis; knowledge query and manipulation language (KQML); multi-agent systems

INTRODUCTION

Electricity Distribution Networks

The electricity distribution industry is one of the largest in the UK, serving nearly 27 million customers. In England and Wales, there are 12 regional electricity companies responsible for distributing and supplying electricity to customers. Electricity is received from the transmission network at 132kV and is transformed down to lower voltages (i.e., 33kV, 11kV, and 240V) as they are distributed across a region. 132kV and 33kV are referred to as high voltage (HV) and 11kV and below as low voltage (LV). Domestic customers receive their supplies at 240V, and some large industrial customers can take their supplies at either 11kV or 33kV (Figure 1).
In the high voltage networks (132kV, 33kV), the circuits are usually equipped with automatic circuit breakers that report their operation to the control centre via the Supervisory Control and Data Acquisition (SCADA) system. These circuit breakers are fitted with an auto-reclosure, which means that when they open automatically due to a fault, after a short delay they will reclose in an attempt to restore the supply. If the fault is transient, the circuit breaker will remain closed, and the power will be restored; but if it is permanent, then the circuit breaker will reopen again to disconnect the supply.

With the low voltage networks (11kV and below), often only outgoing source circuit breakers on 11kV feeders from major substations are telemetered. Below the source circuit breaker, the network is radial with many branches that lead to the 11kV/415V transformers supplying the customers. These branches are protected by protective devices such as fuses, which are not telemetered.

A control engineer who works in the control centre directly controls the network, based upon indications and alarms available to him or her and through the use of telecontrol command schemes. When a fault occurs in the network, no direct information is obtained on what type of fault has occurred and where it is. Rather, telemetry messages obtained in the control centre indicate which switches and automatic protective relays have operated in response to the fault. These telemetry messages normally are regarded as post-fault symptoms, and are vital information to the control engineer when diagnosing faults.

The task of fault diagnosis would be easier if all the relevant switches and protective relays operated correctly. However, fault diagnosis could become quite complex due to factors such as an item of equipment failing to operate when required, or operating when not required. There are other factors: the telemetry messages received are not always in relation to the time the fault occurred, and there is often simply a lack of detailed information regarding the low voltage networks. In some extreme cases (e.g., blizzards, storms, etc.) where several faults occur simultaneously, telemetry messages could arrive at the rate of 2,000 per hour or higher (Brailsford &
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