Optimum Operation and Maintenance of Power Grid Based on Equipment Diagnoses

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Abstract: For optimum operation and maintenance of a transmission and distribution (T&D) system, many events (i.e., equipment failure, outage overload, maintenance, etc.) appeared in the T&D system were converted into cost and the total T&D cost was simulated with the sequential Monte Carlo simulation and nonlinear programming. As a result, it was clarified that the optimum maintenance method varied with the operation year of equipment and the priority of equipment to do maintenance was derived.

Keywords: reliability, maintenance, diagnosis, cost optimum, asset management

1. INTRODUCTION

Modern society requires high power quality and high T&D efficiency. To meet these requirements, as the T&D system contains many aged apparatuses, they have become the major subjects of how and when to do what kind of maintenance of apparatuses and how to minimize the T&D cost including the outage cost. The proposed “Intelligent Grid Management System (IGMS)" provides the solution [1,2]. This paper describes the concept of IGMS and demonstrates its effectiveness. Optimization of the T&D route, minimization of the total expected cost and the optimum maintenance method and schedule were simulated and discussed.

2. CONCEPT OF IGMS

2.1. Basic Concept

The reliability of the T&D system normally increases with the maintenance cost. On the other hand, the damage cost due to system failures decreases as the reliability level increases. The total T&D cost becomes a minimum at which an optimum on target reliability level is achieved and an optimum T&D route is selected.

To realize the minimum total cost, it is necessary to understand and evaluate the present performance of the equipment in the T&D system through diagnosing the equipment and to operate the T&D system based on the present performance of equipment. IGMS makes these functions possible. Fig. 1 shows the IGMS concept. The present performance and the equipment history of operation and maintenance are acquired by diagnostic systems at substations and information systems. All data are collected at the control center. The T&D system is comprehensively evaluated there in terms of the T&D loss, T&D system reliability, overload operation, total cost, etc. Based on the evaluation, the T&D system is operated optimally. Moreover, the maintenance method and schedule of equipment are evaluated and the optimum maintenance strategy is proposed.

2.2. Simulation Procedure

The simulation procedure is shown in Fig. 2. Based on the T&D system data and the equipment reliability, failure patterns of the whole system are calculated chronologically with the sequential Monte Carlo simulation [2]. The optimum power flow route and the T&D cost composed of T&D loss, overload outage, repair and maintenance costs etc. are calculated with nonlinear programming for every system failure pattern. When the optimum equipment reliability and cost are not achieved, the appropriate maintenance is selected to enhance the equipment reliability and the calculation is repeated. Finally the minimum T&D cost and the optimum maintenance strategy are derived.

3. SIMULATION OF MINIMUM T&D COST

3.1. Simulation Conditions

Fig. 3 shows the 275kV network model used in the calculation [2]. Each SS is composed of double bus arrangement. In this calculation, the transformer loss, the Joule loss of transmission lines, maintenance cost, life shorten-
When a CB is overhauled completely, the value of ing of transformer by overload [3,4], outage cost [5], re-
pair cost of equipment [6] were considered.

comes large after a certain operation year (Fig.4 [6]) .

(2) overhaul (OH) and (3) replacement (RP). The failure
rate


circuit breakers (CB). The following three maintenance
should decrease to the value of a new CB. However, as
these CBs than in the other CBs when the operation year
wear parts without exchange may remain, the
be higher than that of a new CB, and the failure rate curve
loads, the total T&D cost per year is more expensive in
and CB5 between SS5 and SS6 are directly connected to
loads. Between 15 to 18 years, the OH-OH-OH case is suitable.
Next, the total T&D cost was calculated by changing
the operation years of CB3, CB4 and CB5. When the op-
eration years of CBs are changed, the expected total
T&D cost per year is shown in Fig. 4. The number of combina-
tions of the three maintenance strategies for three CBs is 27. Calculations were carried out for twenty seven
combinations. Their cost dispersed in the shade region in
Fig. 5. The solid lines show the five combinations which
represent the minimum cost in certain operation years.
The cost is normalized by the cost of one operation year in
RG-RG-RG case.
The maintenance strategy which minimizes the total
T&D cost is the optimum strategy in each operation year.
Between 15 to 18 years, the OH-OH-OH case is suitable.
The OH-RP-OH case is the most economical between 18
to 22 years. The RP-RP-OH case for 22 to 25 years and
the RP-RP-RP case for over 25 years of operation are
recommended. This means that the priority of replacement
is CB4 > CB3 > CB5. This difference in prioritization is
caused by the outage size induced by the CB failure. CB3,
CB4 and CB5 are connected to 40MW, 85MW and 20MW
loads, respectively. Since CB failures result in outage di-
rectly, CB4 which is connected to a large load has high
priority of replacement.

4. CONCLUSION
The effectiveness of Intelligent Grid Management Sys-
tem (IGMS) was basically demonstrated. The T&D sys-
tem failure patterns were simulated with the sequential
Monte Carlo method, and the total T&D cost was calcu-
lated based on nonlinear programming. The possibilities
of both the minimization of the total T&D cost and the
planning of the suitable maintenance strategy according to
the failure rate at an arbitrary operation year were obtained.

REFERENCES
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