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Considerations In Developing And Utilizing Operator Training Simulators

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in data and data sources by comparing the forecast performance of a simulation method using different complete and incomplete data bases.

A test of forecasting data source, collection method, and forecast accuracy was carried out to identify critical elements and costs of data preparation. Among the conclusions are:

1) Single year techniques performed as well as or better than multiyear approaches.
2) Data on the quality and restrictions of vacant land is critical and must be included if accurate forecasts are expected.
3) Data collection effort varies but is not unreasonably high in any case.
4) Data may provide a good fit to present load data and still not produce a good load forecast.

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Penalty Factor Calculations Incorporating Interchange Constraints

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Abstract—The use of penalty factors to account for the effect of transmission losses in the equal incremental cost criterion for economic dispatch of generating units has been firmly established and applied to the real-time dispatch and control. For real-time applications, the methodology has been to generate several sets of *B*-coefficients off-line and select one that approximates the network configuration and the system load level. More recently Jacobian-based algorithms have been proposed and several implementations are reported. Such algorithms have been proven feasible for on-line applications and produce results close to the real-time state of the system. However, most of the existing formulations are based on the overall system behavior and its performance. Whereas, in actual power utility operation interconnected with neighboring companies, the predominant objective is to minimize operational cost while maintaining the net interchange schedule. A Jacobian-based method is presented in this paper for use in such multi-area dispatch problems. The algorithm determines the generator penalty factors for the internal units such that the produced lambda is the incremental cost of delivering power to the load center of the internal area while maintaining a fixed net interchange power. This is in contrast to the Lambda obtained from the single area technique which represents the incremental cost incurred to deliver power to the system load center. In addition, formulation for the penalty factor at the net interchange boundary of the internal area is developed. This is useful for the evaluation of the interchange transactions with the neighboring utilities. The assumptions that have simplified the derivations are 1) the incremental load changes in the internal area may be distributed among the buses in the internal area in a known pattern represented by a set of distribution factors, and 2) the incremental effects of voltage magnitude deviations are negligible. Several studies have verified the above assumptions to be valid for real-time applications where the factors are computed frequently. The method has been successfully tested on several real and study systems. The results are presented and compared with those obtained from the single area technique for a test case.

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Considerations in Developing and Utilizing Operator Training Simulators

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Effective electric system operation depends on strengthening the relationship between the system operator and the electrical system with its associated controls. An operator training simulator (OTS) that simulates the static and dynamic responses of the operator's power system and his control system can increase an operator's knowledge of the behavior of the power system and its response to various controls. The primary use of an operator training simulator is to accelerate and expand the experience of the operator in the operation of his own system.

The requirements for a simulator, while being extremely complex, can be categorized as follows:

a) *the simulator must be realistic* in representing the static and dynamic properties of the trainee's power system;
b) *the man–machine interface should be exact* in that the same CRT displays, the same consoles and the same controls are used as in the real system.

These requirements must be satisfied in order to provide the training necessary to adequately prepare the dispatcher for effective and efficient system operation.

The functional modeling requirements of an effective OTS have been developed in a manner which satisfies these two requirements. The simulator is divided into two functionally distinct parts, a realistic representation of the power system resides in a power system model (PSM), and an exact control center representation resides in the control center model (CCM). The PSM is composed of the mathematical models of the static and dynamic characteristics of the physical electrical network; the simulation of the operational personnel who interact with the operator; and, the simulation of data as gathered from the electrical network and the control commands of the operator (SCADA). The CCM is composed substantially of a replication of the control center computer system, including its entire set of hardware and software. A small portion of the CCM is derived from the need to modify this hardware and software to meet the requirements of the simulation process.

The need to accurately duplicate the control center system significantly constrains the overall OTS configuration. An effective OTS is based on the design that the power system model resides in a separate dedicated computer system configured to meet its distinct needs. The control center model is configured on the same kind of hardware as used in the control center (or an essentially identical computer system). The power system model design is modular in order to allow each utility to tailor the simulator to its own unique configuration. The PSM can be developed with a minimum set of simulation capabilities, while other functions can be added at a later time as required by the implementing utility.

Once a simulation is started, the PSM goes into a tracking mode which is used when the power system is operating under quiescent scenario conditions. The tracking mode continues until interrupted by a planned or trainee-initiated event. After processing the event, the PSM resumes the tracking mode until the next event. The PSM is able to analyze the resulting long-term dynamic and steady-state effects triggered by control actions taken by the trainee. However, certain control actions may alter or invalidate later events in the scenario. A form of heuristics is proposed to handle these events. During the building of the scenario, the engineer/instructor would determine which system conditions would most likely require operator action. An off-line transient/mid-term/long-term dynamic analysis would be made to determine the effects of the operator action. The results of those operator actions which have significant effect on the system can be saved as part of the scenario and incorporated into the working scenario at the appropriate time.

This paper has presented a set of guidelines developed for a generic operator training simulator system which can be applied to all levels of digital computer based energy control systems. The objective of these guidelines is to outline the OTS requirements and then establish a design which when implemented can be utilized by many utilities, irregardless of their control center configuration. The concepts developed in this paper are based on work of the project team through a project funded by the Electric Power Research Institute.

Discussers: K. Hemmaplardh, H. Biglari, and S. A. Sackett.

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Transformer Tap Position Estimation

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Abstract—The estimation of voltage transformer tap position is a desirable feature that can be appended to most state estimation algorithms. The primary requirement to estimate transformer tap position is the availability of a three-phase reactive-power measurement through either the fixed or tap side of the transformer. These "measured" flows can also be calculated, depending on the availability of reactive injection and reactive transmission line flow measurements around the fixed or tap side buses. The gain matrix of the state estimator is not modified so only the tables used to calculate real and reactive residual mismatch need to be updated during the state estimator solution. The computational cost of including transformer tap position estimation is extra iterations of the state estimator. A number of tests were conducted using the IEEE 118 bus system as a model. The results of one of these tests are presented along with the algorithm to modify the tap positions while the State Estimator solution proceeds. A practical stopping criterion for the algorithm is also presented. The extension of the algorithm to line parameter estimation is also discussed in the Appendix.

Introduction

The ability to estimate voltage transformer tap position has gained importance due to the widespread use of state estimation and load flow programs in energy control centers. Initially, real-time load flows and state estimators covered a limited area, usually consisting of only the "backbone" of the system. The current practice of many companies is to apply the state estimator to cover the system down to the subtransmission network. The load flow is sometimes taken down as far as the distribution network. In order for the state estimator and load flow to produce reliable and consistent results, an adequate measurement set must be telemetered to the control center. This measurement set typically consists of breaker status, real and reactive power line flows, real and reactive bus injections, bus voltages, and some transformer tap positions. Many utilities do not currently telemeter all of the transformer tap positions that the load flow and state estimator programs require to produce a reliable voltage profile. This is particularly apparent when the state estimator produces a number of large reactive power residuals that are all associated with transformers.

There are several conditions that occur in practice that can cause an incorrect tap position to be entered in the data base. If the transformer tap is not controllable, its tap position could have been entered incorrectly, or not at all, or its tap position could have been entered correctly but the tap position manually changed and the change not entered into the data base. If the transformer has a tap position that can be controlled through the SCADA system the tap position could be incorrectly measured. For the case of a transformer under local control (TCUL) the tap position is sometimes not telemetered back so the tap position is not known on a real-time basis to either the state estimator or the load flow.

After some investigation it was determined that the most reliable indication of transformer tap position was the difference between the measured reactive flow through the transformer and the calculated reactive flow the state estimator produces. This relatively strong coupling between the transformer tap position and the reactive power flow through the transformer is the basis of the transformer tap estimation algorithm.

Tap Position Estimation

In order to successfully estimate transformer tap position a number of conditions must be met.

1) A measured or directly calculated reactive power flow through either the fixed or tap side of the transformer must be available. There must be a high degree of confidence that the measurement or pseudomeasurement is correct within the accuracy limitations of the meters that are used.
2) The transformer reactance must be known and this reactance must be on the correct side of the tap, depending on the transformer manufacturer's specifications.
3) The reactive power flow through the transformer must not be strongly influenced by another transformer whose tap is also being modified by the algorithm.
4) Full reactive convergence must be achieved (particularly when the estimated tap position is near the actual position) before the next iteration of the tap estimation algorithm is taken.
5) The effects of transformer magnetizing impedance must be negligible.

Transformer saturation is assumed to have a negligible influence on tap estimation.

Discussers: Louis S. VanSlyck and Jorge F. Dopazo.

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An Approach to Real-Time Reactive Monitoring for System Security

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This paper, resulting from a study performed by the Pennsylvania–New Jersey–Maryland Interconnection (PJM) with Gilbert/Commonwealth, presents a conceptual overview of a real-time reactive monitoring approach. The selected approach is an integrated multifunctional system which represents the best of present technology available to meet PJM's program objectives. The monitoring system features continuous reactive and thermal contingency analysis, reallocation of reactive sources, and a study capability, to provide the most reliable and economic mode of operation.

PJM is comprised of seven electric utilities serving approximately 48 700 square miles. The interconnection office coordinates the operation of all generation and bulk power transmission to provide reliable and economic power to the customers of the member companies. The PJM bulk power transmission system is operated so that