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Task Force on System Studies

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Procedure for Analysis and Classification of Dynamic Control Systems

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1 INTRODUCTION

1.1 Scope

The NPCC *Guidelines for NPCC AREA Transmission Reviews* (Document B-4) calls for testing Dynamic Control Systems in order to classify them in terms of their impact on the **NPCC Bulk Power System (BPS)**.[1]

The purpose of this procedure is to provide a set of objectives and procedures applicable to the analysis and classification of Dynamic Control Systems on the **NPCC Bulk Power System**. This procedure should be used when testing Dynamic Control Systems for NPCC studies or studies submitted for NPCC review. (Terms in bold typeface are defined in the Glossary located in Document A-7, the *NPCC Glossary of Terms*.)

1.2 Definitions

A Dynamic Control System is defined as a continuously-acting control system which responds to normal and abnormal system conditions or events so as to enhance **Bulk Power System** stability by acting upon one or more power system quantities such as voltage, current, or power as determined by measurement of one or more power system parameters. Dynamic Control Systems include, for example, Static Var Compensators, Synchronous Condensers, and other Flexible AC Transmission System (FACTS) devices, and the following portions of high voltage direct current (**HVdc**) systems, generator excitation systems, and turbine governor systems:

HVdc Systems: Converter Control (including any disturbance recovery auxiliary features); Voltage-Dependent Current Order Limit (VDCOL); ac Network Frequency Control; Power Modulation; Reactive Power Control; Fast dc Power Change; Subsynchronous resonance (SSR) damping; and any related measurement devices.

Generator Excitation Systems: Automatic Voltage Regulator (AVR); Power System Stabilizer (PSS); Under-excitation limiter; and any related measurement devices.

Turbine Governor Systems: Early valve actuation or "fast-valving" systems are assumed to come under the definition of an SPS. Although governors come under a strict interpretation of the Dynamic Control System definition above, they are considered to be too slow in response to significantly influence **BPS** performance.

Note, for example, that mechanically-switched reactive compensation, fixed compensation[2], tap changing transformers, phase angle regulators, and over-excitation limiters on generators are not considered to be Dynamic Control Systems.

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[1] The NERC *Planning Standards* III.B *Transmission Control Devices* Measure M1 proposes that "When planning new or substantially modified transmission control devices, transmission owners shall evaluate the impact of such devices on the reliability of the interconnected transmission systems". The NERC *Planning Standards* III.C *Generation Control and Protection* also calls for assessment of generator controls.

Subsystems are defined as portions of a Dynamic Control System which are functionally related, may be geographically separate, and together serve to perform the overall function of that Dynamic Control System.[3]

1.3 Classification

Dynamic Control Systems are sub-divided into three types. Reference can be made to the NPCC *Basic Criteria for Design and Operation of Interconnected Power Systems* (Document A-2) where "Design Contingencies" are described in Sections 5.0 and 6.0 and "Extreme Contingencies" are described in Section 7.0.

Type I Those Dynamic Control Systems whose incorrect operation or failure to operate following a Design Contingency would have **significant adverse impact** outside the local area. The correct response delivered by these Dynamic Control Systems is intended to return power system parameters to a stable and recoverable state.

The design practices contained in Appendix C should be considered for Type I Dynamic Control Systems.

Type II Those Dynamic Control Systems, installed for the purpose of mitigating the impact outside the local area of Extreme Contingencies. In the application of these Dynamic Control Systems, security is the prime concern. The design considerations relating to dependability in Appendix C do not necessarily apply.

Type III Those Dynamic Control Systems whose incorrect operation or failure to operate results in no **significant adverse impact** outside the local area. The design practices contained in Appendix C may or may not be considered for Type III Dynamic Control Systems. It should be recognized that Type III Dynamic Control Systems may, due to system changes, become Type I or Type II.

1.4 Coordination

With Dynamic Control Systems, it is imperative that system planning, design and engineering, protection, operating, and maintenance functions closely coordinate, since initially and throughout their life cycle, Dynamic Control Systems are a multi-discipline concern. Dynamic Control System and protection functional settings and operational procedures should be reviewed whenever significant changes in generating sources, transmission facilities, or operating conditions are anticipated.

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[2] Except where they form a subsystem of a larger Dynamic Control System.

[3] Note that NPCC's definition of Dynamic Control Systems above includes generator controls, whereas NERC's definition of Transmission Control Devices does not. Conversely, NERC's definition of Transmission Control Devices includes the consideration of mechanically-switched shunt capacitors and reactors, whereas NPCC's definition of Dynamic Control Systems does not.

2 PERFORMANCE CONSIDERATIONS

Potential failure of a single component that could affect operation of multiple Dynamic Control Systems at one location should be assessed in the testing procedure by failing at least two Dynamic Control Systems simultaneously.

Stability of the **BPS** should be maintained during and after the most severe of the Design Contingencies listed in Section 5.1 of the *Basic Criteria*, while any single Dynamic Control System is experiencing a single undetected failure. As stated in Section 5.2 of the *Basic Criteria*, voltages and line and equipment loadings shall be within normal limits for pre-disturbance conditions and within applicable emergency limits for the system conditions that exist following the contingencies specified in Section 5.1 of the *Basic Criteria*.

Pre-contingency load flows chosen for this analysis should reflect reasonably stressed power transfer conditions within Areas, or Area to Area; these are expected to be similar to conditions used to demonstrate compliance to the *Basic Criteria* under the guidelines in Document B-4.

3 PROCEDURE FOR CLASSIFICATION

A flow chart describing the procedure for classifying a Dynamic Control System as Type I or III is provided in Appendix A.

Note that for the purpose of classification, these tests generally fix the device at the pre-contingency operating point, restricting the dynamic response.

For example, for AVRs, the test considers a fixed field voltage E_{fd} with a design contingency fault. For failure modes other than those that result in a fixed E_{fd}, it is assumed that either existing protection systems would remove the generator from service, or operators would recognize an abnormal condition and place the excitation system on manual control.

Appendix B shows a list of suggested tests for different Dynamic Control Systems in NPCC.

3.1 Testing for Type I Classification

A single undetected failure should not result in **significant adverse impact** outside the local area.

If any undetected failure of a single Dynamic Control System component or subsystem during and after any of the Design Contingencies listed in Section 5.1 of the Basic Criteria results in **significant adverse impact** outside the local area, that Dynamic Control System is classified as Type I.

3.2 Testing for Type II Classification

If any undetected failure of a single Dynamic Control System component or subsystem during and after any of the Extreme Contingencies listed in Section 7.0 of the Basic

Criteria results in **significant adverse impact** outside the local area, that Dynamic Control System is classified as Type II.

In general, Type II Dynamic Control Systems do not need to include redundancy provided that their design is secure.

3.3 Testing for Type III Classification

If any undetected failure of a single Dynamic Control System component or subsystem during and after the most severe of the Design Contingencies listed in Section 5.1 of the Basic Criteria results in no **significant adverse impact** outside the local area, that Dynamic Control System is classified as Type III.

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Review frequency: 3 years

References:

Basic Criteria for Design and Operation of Interconnected Power Systems (Document A-2)

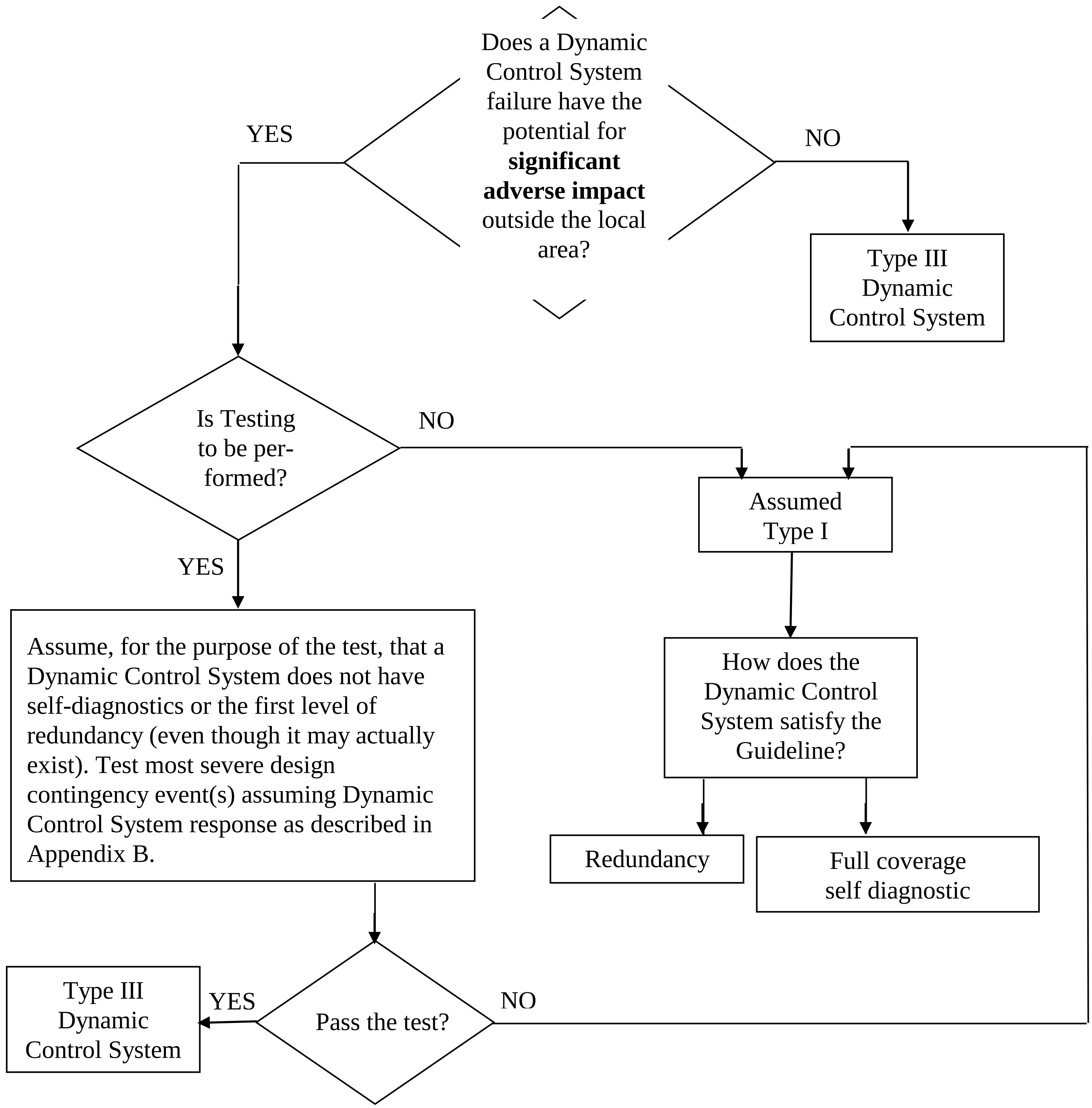
NPCC Glossary of Terms (Document A-7)

Guidelines for NPCC AREA Transmission Reviews (Document B-4)

NERC Planning Standards

Appendix A

Classifying Dynamic
Control Systems as Type I or Type III



Appendix B

SUGGESTED TESTS FOR CLASSIFYING DYNAMIC CONTROL SYSTEMS IN NORTHEAST POWER COORDINATING COUNCIL

1. Generator Excitation AVRs

Design contingency fault with fixed field voltage, Efd

2. Power System Stabilizers (PSS)

Design contingency fault with inoperative PSS

3. Static Var Compensator, Synchronous Condenser, and other FACTS device

Design contingency fault with fixed pre-disturbance operating point at fault clearing

4. HVdc

Design contingency fault with the worst single failure of the following:

a. fixed converter firing angle

b. inoperative VDCOL

c. fixed frequency control

d. fixed power modulation

e. fixed reactive power control

f. inoperative fast dc power change

g. inoperative SSR damping

Appendix C

SUGGESTED DESIGN CONSIDERATIONS FOR DYNAMIC CONTROL SYSTEMS

Introduction

The general objective for any Dynamic Control System is to perform its intended function (for example, field current control of a generator, rapid voltage regulation and var production, power swing damping, etc.) in a dependable and secure manner. For Dynamic Control Systems, dependability is that facet of reliability that relates to the degree of certainty that the system will function correctly. Security is that facet of reliability which relates to the degree of certainty that the system will not operate incorrectly.

Dynamic Control Systems are intended to operate in response to measured power system conditions. The relative effects on the **BPS** of the failure to operate when desired or an incorrect operation versus an unintended operation should be weighed carefully in selecting design parameters as described further below.

The general objective can only be met if the Dynamic Control System can reliably respond to the specific conditions for which it is intended to operate and exhibit an acceptable response for other system conditions.

Dependability and Security

To enhance dependability, Type I Dynamic Control Systems should be designed such that the Dynamic Control System is capable of performing its intended function under the specified design contingencies, while itself experiencing a single undetected failure. This implies that failures which are not detectable by specific sub-systems designed for that purpose, or by operator observation, should be covered by functional redundancy. To enhance security, Type I and Type II Dynamic Control Systems should be designed such that the Dynamic Control System itself does not cause **BPS significant adverse impact**, while the Dynamic Control System is experiencing a single failure independent of any design contingency condition. These considerations are reflected in the performance considerations described in Section 2 of this procedure.

In achieving the above goal, duplication, as a means of achieving functional redundancy, should be used with caution and thorough design evaluation. For example, the choice of duplication as a means of providing functional redundancy improves the dependability of a properly designed and tested Dynamic Control System but, since it may increase the probability of an unintended operation, it can also jeopardize security.. In addition, design weaknesses which go undetected during the planning, design, and commissioning phases of a Dynamic Control System may degrade the dependability afforded by duplication. This is because the design weakness may also be duplicated and may result in inappropriate control action from both redundant systems. Finally, simple duplicate control systems may result in an inability to decide which of the two is giving the correct response.

Duplication of Dynamic Control Systems may not be necessary or appropriate if the performance considerations Section 2 of this procedure can be achieved through functional redundancy. For example, in the case of Dynamic Control System with microprocessor-based controls, duplication may be unnecessary if any failure within the microprocessor-based control can be detected and reported by self-diagnostic features, and appropriate action can be taken.

In any case, whether functional redundancy is achieved by means of physical duplication, backup subsystems, or fail-safe design with operator alarms, all Type I and Type II Dynamic Control Systems should be subjected to a design evaluation by the member system.

The dependability considerations for a Dynamic Control System apply only with respect to its response to the system conditions to which it is designed to respond. However, the security considerations for a Dynamic Control System apply with respect to its performance under normal **BPS** conditions as well as its response to any design or extreme contingency.

The above considerations imply the necessity to avoid the use of components common to redundant Dynamic Control Systems or subsystems of a Dynamic Control System. Areas of common exposure should be kept to a minimum to reduce the possibility of any physically or functionally redundant subsystems being disabled by a single contingency.

All of the provisions of the section of the NPCC Bulk Power System Protection Criteria entitled "Considerations Common to Dependability and Security” should apply to all subsystems of Dynamic Control Systems having prime purpose of protection, control, or measurement.

Dynamic Control System Testing and Maintenance

The design of Dynamic Control Systems, both in terms of circuitry and physical arrangement, should facilitate periodic testing and maintenance in a manner that mitigates the risk of **significant adverse impact**. As Dynamic Control Systems may be complex and may interface with other Dynamic Control Systems and/or protection systems, special attention should be placed on ensuring that test devices and test interfaces properly support a clearly defined maintenance strategy.

Sufficient testing should be employed on commissioning, when modifications are made, and periodically, to ensure that Dynamic Control System settings are as specified and that response characteristics are within design limits.

Type I Dynamic Control Systems that have been in service beyond the break-in period should be maintained at least every 2 years. This suggestion is based on the experience and judgement of NPCC members. This maintenance interval should result in dependable and secure Dynamic Control System operation. There are reasons peculiar to many individual situations which will justify more frequent maintenance intervals. Each member system should evaluate its own particular circumstances and determine if any additional maintenance should be performed on the Dynamic Control Systems on its system.

Minimum maintenance of Dynamic Control Systems includes verifying inputs and outputs, making visual inspections, and performing other operational tests to assure satisfactory operation of the equipment as a system.

It is also recommended that the operation of a Dynamic Control System as a system be periodically checked between maintenance intervals by monitoring its response to a natural change in the power system or to a small perturbation initiated by a test.

Sufficient checks should be made periodically to ensure that instrument transformers, control batteries, and chargers are in proper operating condition.

Each time the Dynamic Control System is maintained, the Dynamic Control System hardware should be tested as a system to ensure compatibility and correct operation.

If a segmented testing approach is used, test procedures and test facilities should ensure that related tests properly overlap. Proper overlap is ensured if each portion of circuitry is seen to perform its intended function, from either a real or test stimulus, while observing some common reliable downstream indicator.

Wherever practical, the testing objectives of maintenance may be met by documenting actual events. Such an approach can reduce the probability of incorrect operation during maintenance while effectively reducing the extent of planned maintenance.

Test facilities or test procedures should be designed such that they do not compromise the independence of redundant Dynamic Control Systems or Dynamic Control System subsystems.

Analysis of Dynamic Control System Performance

To ensure the design parameters have been selected properly and that Dynamic Control System performance is correct, analysis of Dynamic Control System operation should be performed as outlined below.

Dynamic Control System response to significant **BPS** events should be analyzed for proper Dynamic Control System performance. Corrective measures should be taken promptly if a Dynamic Control System or one or more of its subsystems fail to operate or operate incorrectly.

Sequence-of-events recorders, oscillographs, disturbance monitors, etc., should be provided to the maximum practicable extent to permit analysis of system disturbances and Dynamic Control System performance. Criteria for these types of devices are described in Document A-2, paragraph 2.3.