

Composite Reliability Impacts of Synchronphasor-Based DTR and SIPS Cyber–Physical Systems

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Abstract—The integration of smart infrastructures that facilitate two-way communication via information and communication technology (ICT) has enhanced the efficiency and sustainability of the power network. However, technologies, such as dynamic thermal rating (DTR) systems and system integrity protection schemes (SIPS), have disadvantages, including infrastructure failures, cyber–physical interdependencies, and cyber intrusions. These disadvantages contribute to the reduced reliability of the network. Comprehensive exploration of the reliability impacts of multiple smart grid technologies on a single power network has not been conducted. A DTR and SIPS system integrating wide area monitoring functions using phasor measurement units (PMUs) is presented in this study, and the effect of ICT contingencies on network reliability is investigated. A Monte Carlo simulation approach and a scenario reduction technique are utilized in this article. This approach is evaluated on the IEEE-RTS to demonstrate the advantages of ICTs. The approach is suitable for different network topologies, in which the difference lies in the number of required PMUs. Results demonstrate that a reliable SIPS can minimize the aging process while slightly influencing load curtailment despite the increase in overall network aging due to DTR. PMU functional failures result in load loss due to loss of observability despite their high availability.

Index Terms—Composite system reliability, cyber–physical systems, dynamic thermal rating (DTR), generation rejection scheme (GRS), information and communication technology (ICT), overhead line aging, phasor measurement unit (PMU), smart grid, system integrity protection schemes (SIPS).

NOMENCLATURE

DTR	Dynamic thermal rating.
EDLC	Expected duration of load curtailment.
EENS	Expected energy not supplied.
ENLC	Expected number of load curtailment
ETNA	Expected total network aging.

GRS	Generation rejection scheme.
ICT	Information and communication technology.
MDT	Maximum designed temperatures.
OHL	Overhead lines.
PDC	Phasor data concentrator.
PLC	Probability of load curtailment.
PMU	Phasor measurement unit.
RTN/RTS	Reliability test network/system.
SMCS	Sequential Monte Carlo simulation.
SIPS	System integrity protection scheme.
TSO	Transmission system operator.
WAM	Wide area monitoring
AB	Set of all adjacent buses.
AL	Set of all adjoining lines.
B	Set of all buses.
GB	Set of all generation buses.
L	Set of all transmission lines.
LB	Set of all load buses.
OL	Set of all observable lines.
UL	Set of all unobservable lines.
A_c^i	Availability of a component c .
AB_{PMU}	Adjacent buses to PMU buses.
B_{PMU}	PMU bus.
$BrObs(L)$	Branch observability.
$BusObs(B)$	Bus observability.
PF_l	Power flow capacity of line l .
$PF_l^{\max}$	Maximum power flow capacity of line l .
PF_l^{STR} / PF_l^{DTR}	STR/DTR value of line power flow capacity.
S^x	State of a component x .
X_l	Reactance of line l .
$\vartheta_{fb} / \vartheta_{tb}$	Voltage phase angle of from bus/to bus.

I. INTRODUCTION

EXCEPTIONAL advantages in the general efficiency improvement of power grids have been observed with the advancement of conventional power systems to smart cyber–physical power networks. Information and communication technology (ICT), which improves the power network through intelligent technology to enable its operations, is a crucial component of the smart grid. Physical and cyber networks are found in cyber–physical networks. Therefore, interdependencies between components and networks, which influence one another, are undeniably observed [1]–[3]. Power systems gain considerable benefits with ICT implementation; however, such an implementation also presents imminent

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