

Impacts of Communication Network Availability on Synchrophasor-Based DTR and SIPS Reliability

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Abstract—The modern electricity network has become smarter and more reliable because of the addition of information and communication technology. Dynamic thermal rating systems (DTR) allow existing transmission lines to be operated much closer to their limits. However, line outages after DTR implementation could threaten network security. Thus, system integrity protection schemes (SIPS), which are designed to ensure security, are useful to forestall impending contingencies that could arise from DTR implementation. Furthermore, synchrophasors can improve wide-area monitoring and protection capabilities. However, the reliability of these technologies considering their communication network availability is yet to be studied in a unified framework. Therefore, a novel framework of synchrophasor-based DTR and SIPS is presented while examining eight DTR network topologies and two SIPS schemes simultaneously. A sequential Monte Carlo simulation-based technique is proposed to simulate the effect of the topologies on system-wide reliability. This method is tested on the IEEE-RTS. Results show an improvement of 93.27% between DTR communication Schemes 1 and 8 in load curtailment. More importantly, the article reveals an improvement of 99.15% in the load curtailment value in scenarios where SIPS is deployed compared with the case where SIPS is not deployed, highlighting the benefits of DTR and SIPS hybrid implementation.

Index Terms—Cyber-physical systems, dynamic thermal rating (DTR) systems, generator rejection scheme (GRS), phasor measurement units (PMUs), power system reliability, system integrity protection schemes (SIPS).

NOMENCLATURE

Abbreviation

BS	Bay switch.
CB	Circuit breaker.
DBM	Dependability-based misoperation.
DTR	Dynamic thermal rating.
EDCO	Expected duration of communication network outage.
EDLC	Expected duration of load curtailment.
EENS	Expected energy not supplied.

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ENLC	Expected number of load curtailment.
GRS	Generation rejection scheme.
ICT	Information and communication technology.
IED	Intelligent electronic device.
OPF	Optimal power flow.
PCNO	Probability of communication network outage.
PDBM	Probability of DBM failure.
PDC	Phasor data concentrator.
PMU	Phasor measurement unit.
PS	Process switch.
PSBM	Probability of SBM.
RTN/RTS	Reliability test network/system.
SBM	Security-based misoperation.
SMCS	Sequential Monte Carlo simulation.
SIPS	System integrity protection scheme.
SS	Station switch.
STR	Static thermal rating.
TSO	Transmission system operator.
WAMP	Wide area monitoring and protection.
<i>Sets</i>	
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.

Parameters

A_c	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^c	State of a component c .
X_l	Reactance of line l .
$\vartheta_{fb} / \vartheta_{tb}$	Voltage phase angle of from bus/to bus.

I. INTRODUCTION

DYNAMIC thermal rating (DTR) systems calculate increased line ampacities based on real-time weather information instead of using conservative static thermal rating