Lecture Notes in Electrical Engineering 580

Reji Kumar Pillai
Girish Ghatikar
Ravi Seethapathy
Vijay L. Sonavane
S. A. Khaparde
Pradeep Kumar Yemula
Samir Chaudhuri *Editors*

ISGW 2018 Compendium of Technical Papers

4th International Conference and Exhibition on Smart Grids and Smart Cities

Springer

Lecture Notes in Electrical Engineering

Volume 580

Series Editors

Leopoldo Angrisani, Department of Electrical and Information Technologies Engineering, University of Napoli Federico II, Naples, Italy
Marco Arteaga, Departament de Control y Robótica, Universidad Nacional Autónoma de México, Coyoacán, Mexico
Bijaya Ketan Panigrahi, Electrical Engineering, Indian Institute of Technology Delhi, New Delhi, Delhi, India
Samarjit Chakraborty, Fakultät für Elektrotechnik und Informationstechnik, TU München, Munich, Germany
Jiming Chen, Zhejiang University, Hangzhou, Zhejiang, China
Shanben Chen, Materials Science and Engineering, Shanghai Jiao Tong University, Shanghai, China
Tan Kay Chen, Department of Electrical and Computer Engineering, National University of Singapore, Singapore, Singapore
Rüdiger Dillmann, Humanoids and Intelligent Systems Lab, Karlsruhe Institute for Technology, Karlsruhe, Baden-Württemberg, Germany
Haibin Duan, Beijing University of Aeronautics and Astronautics, Beijing, China
Gianluigi Ferrari, Università di Parma, Parma, Italy
Manuel Ferre, Centre for Automation and Robotics CAR (UPM-CSIC), Universidad Politécnica de Madrid, Madrid, Spain
Sandra Hirche, Department of Electrical Engineering and Information Science, Technische Universität München, Munich, Germany
Faryar Jabbari, Department of Mechanical and Aerospace Engineering, University of California, Irvine, CA, USA
Limin Jia, State Key Laboratory of Rail Traffic Control and Safety, Beijing Jiaotong University, Beijing, China
Janusz Kacprzyk, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland
Alaa Khamis, German University in Egypt El Tagamoa El Khames, New Cairo City, Egypt
Torsten Kroeger, Stanford University, Stanford, CA, USA
Qilian Liang, Department of Electrical Engineering, University of Texas at Arlington, Arlington, TX, USA
Ferran Martin, Departament d’Enginyeria Electrònica, Universitat Autònoma de Barcelona, Bellaterra, Barcelona, Spain
Tan Cher Ming, College of Engineering, Nanyang Technological University, Singapore, Singapore
Wolfgang Minker, Institute of Information Technology, University of Ulm, Ulm, Germany
Pradeep Misra, Department of Electrical Engineering, Wright State University, Dayton, OH, USA
Sebastian Möller, Quality and Usability Lab, TU Berlin, Berlin, Germany
Subhas Mukhopadhyay, School of Engineering & Advanced Technology, Massey University, Palmerston North, Manawatu-Wanganui, New Zealand
Cun-Zheng Ning, Electrical Engineering, Arizona State University, Tempe, AZ, USA
Toyoaki Nishida, Graduate School of Informatics, Kyoto University, Kyoto, Japan
Federica Pascucci, Dipartimento di Ingegneria, Università degli Studi “Roma Tre”, Rome, Italy
Yong Qin, State Key Laboratory of Rail Traffic Control and Safety, Beijing Jiaotong University, Beijing, China
Gan Woon Seng, School of Electrical & Electronic Engineering, Nanyang Technological University, Singapore, Singapore
Joachim Speidel, Institute of Telecommunications, Universität Stuttgart, Stuttgart, Baden-Württemberg, Germany
Germano Veiga, Campus da FEUP, INESC Porto, Porto, Portugal
Haitao Wu, Academy of Opto-electronics, Chinese Academy of Sciences, Beijing, China
Junjie James Zhang, Charlotte, NC, USA

The book series *Lecture Notes in Electrical Engineering* (LNEE) publishes the latest developments in Electrical Engineering - quickly, informally and in high quality. While original research reported in proceedings and monographs has traditionally formed the core of LNEE, we also encourage authors to submit books devoted to supporting student education and professional training in the various fields and applications areas of electrical engineering. The series cover classical and emerging topics concerning:

- Communication Engineering, Information Theory and Networks
- Electronics Engineering and Microelectronics
- Signal, Image and Speech Processing
- Wireless and Mobile Communication
- Circuits and Systems
- Energy Systems, Power Electronics and Electrical Machines
- Electro-optical Engineering
- Instrumentation Engineering
- Avionics Engineering
- Control Systems
- Internet-of-Things and Cybersecurity
- Biomedical Devices, MEMS and NEMS

For general information about this book series, comments or suggestions, please contact leontina.dicecco@springer.com.

To submit a proposal or request further information, please contact the Publishing Editor in your country:

China

Jasmine Dou, Associate Editor (jasmine.dou@springer.com)

India

Aninda Bose, Senior Editor (aninda.bose@springer.com)

Japan

Takeyuki Yonezawa, Editorial Director (takeyuki.yonezawa@springer.com)

South Korea

Smith (Ahram) Chae, Editor (smith.chae@springer.com)

Southeast Asia

Ramesh Nath Premnath, Editor (ramesh.premnath@springer.com)

USA, Canada:

Michael Luby, Senior Editor (michael.luby@springer.com)

All other Countries:

Leontina Di Cecco, Senior Editor (leontina.dicecco@springer.com)

**** Indexing: The books of this series are submitted to ISI Proceedings, EI-Compendex, SCOPUS, MetaPress, Web of Science and Springerlink ****

More information about this series at http://www.springer.com/series/7818

Reji Kumar Pillai · Girish Ghatikar ·
Ravi Seethapathy · Vijay L. Sonavane ·
S. A. Khaparde · Pradeep Kumar Yemula ·
Samir Chaudhuri
Editors

ISGW 2018 Compendium of Technical Papers

4th International Conference and Exhibition on Smart Grids and Smart Cities

Springer

Editors
Reji Kumar Pillai
India Smart Grid Forum (ISGF)
New Delhi, Delhi, India

Girish Ghatikar
Electric Power Research Institute (EPRI)
Palo Alto, CA, USA

Ravi Seethapathy
Biosirus
Markham, ON, Canada

Vijay L. Sonavane
Former Member (Tech)
MERC
Mumbai, Maharashtra, India

S. A. Khaparde
Department of Electrical Engineering
Indian Institute of Technology Bombay
Mumbai, Maharashtra, India

Pradeep Kumar Yemula
Department of Electrical Engineering
Indian Institute of Technology Hyderabad
Hyderabad, Andhra Pradesh, India

Samir Chaudhuri
Chair Working Group 7
India Smart Grid Forum (ISGF)
New Delhi, Delhi, India

ISSN 1876-1100 ISSN 1876-1119 (electronic)
Lecture Notes in Electrical Engineering
ISBN 978-981-32-9118-8 ISBN 978-981-32-9119-5 (eBook)
https://doi.org/10.1007/978-981-32-9119-5

© Springer Nature Singapore Pte Ltd. 2020
This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.
The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Contents

Smart Grid Technology

Advanced Distribution Management System: An Integrated System

Tarun Bhardwaj, Aakash Verma and Virender Mittal

Abstract Tata Power-DDL has been the frontrunner in implementing power distribution reforms in the capital city and is acknowledged for its consumer friendly practices. The company has implemented high-tech automated systems for its entire distribution network. In the world of digitalization, TATA POWER-DDL adopted smart technologies like SCADA-DMS and OMS to improve reliability and customer outages. These were implemented at different times, from different vendors and operated in different environments resulting in inefficient outage durations, non-optimal costs, and customer dissatisfaction. The flow of information from DMS to OMS happens through ICCP, but no reverse flow of information from OMS to DMS happens. Consequently, the DMS dispatchers have no clue as to the impact of outages on customers and OMS dispatchers have little clue about the cause of outages. This often results in delayed and to some extent, inaccurate information being conveyed to the customers, and no benefit accruing to reliability from customer calls. For better efficiency, digitalization of network and outage management, accurate reporting integration of the two systems was required. However, technological integration was beyond question due to the incompatibilities in technologies, vendors and data systems. So Advance Distribution Management System (ADMS) has been implemented to manage all levels of outages efficiently. This system acts as an integrator between all IT & OT systems, which is integrated with SAP-CRM, GIS, MWM/FFA,ICCP, Power manager portfolio, SAP BW-BO, RTU/DCU/FRTU/IED, Social media etc. In the near future we are going to integrate it with EV charging Solar Roof top, Battery storage, micro grids, Energy Audit, DPS (CYME, ETAP), HES, MDMS, ADR etc. Thus, ADMS is going to be the biggest integrator in the utility sector which will lead us towards the digitalization of our utility. This will also lead to desired improvements in

T. Bhardwaj (✉) · A. Verma · V. Mittal
Tata Power Delhi Distribution Ltd., New Delhi, India
e-mail: tarun.bh@tatapower-ddl.com

A. Verma
e-mail: aakash.verma@tatapower-ddl.com

V. Mittal
e-mail: virendra.mittal@tatapower-ddl.com

© Springer Nature Singapore Pte Ltd. 2020

R. K. Pillai et al. (eds.), *ISGW 2018 Compendium of Technical Papers*,
Lecture Notes in Electrical Engineering 580,
https://doi.org/10.1007/978-981-32-9119-5_1

reliability and customer outage services. This paper attempts to outline and analyze the issues in the old system and explain how the new system has addressed those issues and added value to the utility by improving reliability and customer services simultaneously.

Keywords SCADA-DMS · OMS · ADMS · RTU · DCU · FRTU · IED · DPS · MDMS · HES · ADR · MWM & ICCP

Abbreviations

Tata Power-DDL	Tata power Delhi distribution Limited
ADMS	Advanced distribution management system
SCADA	Supervisory control and data acquisition
EMS	Energy management system
DMS	Distribution management system
OMS	Outage management system
GIS	Geographical information system
ERP	Enterprise resource planning
GSAS	Grid sub-station automation system
DA	Distribution automation
AT& C	Aggregate technical and commercial
SAIDI	System average interruption duration indices
SAIFI	System average interruption frequency indices
CMI	Consumer minutes interruption
ADR	Automatic demand response
DER	Distributed energy resource
BESS	Battery energy storage system
FFA	Field force automation
AMI	Advanced metering infrastructure
APRS	Automated power restoration system
SA	Switching advisor
IVVC	Integrated Volt/VAR control
OFR	Optimal feeder reconfiguration
NOC	Normal operating condition
AVL	Automated vehicle locator
CIM	Common information model

1 Introduction

Tata Power Delhi Distribution Limited is a Power Distribution Utility, distributes electricity in North and North- West part of Delhi, serving about 1.5 million consumers. Reliability and Aggregate Technical & Commercial (AT&C) Losses are the most important criteria for Regulators for measuring performance of any Power Utility. TATA POWER-DDL has been forerunner in implementing power distribution reforms in its licensee area to reduce AT& C Loss and improve reliability and consumer delight.

In present era of industrial and technological development, purpose of electricity is not only to supply power to bulb and fan but to life support systems, essential lifesaving services, water treatment plants, commutation and communication infrastructure, continuous process industries, cooling and heating appliances etc. In this aspect, responsibility of power utility is not just provide power availability to their consumer but also with quality and services. Hence the definition of Reliability is not limited to subside power outages but to provide quality of power with services which improve customer satisfaction. In this context reliability is basically measure of overall effectiveness of distribution utility which includes:

- Availability of Power to meet demand of all consumers at all time.
- Secured network to transmit power to consumer premises in all contingencies.
- Deliver power within accepted standards desired for delicate electrical appliances and gadgets.
- Provide consumer friendly services to meet their expectation and satisfaction.

To improve the reliability TATA POWER-DDL had already taken so many conventional measure like augmentation of existing network, segregation of long feeders, providing protective device with proper coordination at optimized location, adding sectionalizing and load break switch at proper location, improving lightening protection, introducing covered conductor and bird guard etc. In addition to these conventional method, some progressive technology has been adopted to enhance reliability and consumer satisfaction.

- Supervisory Control and Data Acquisition (SCADA) along with Grid Sub-station Automation System (GSAS): to monitor and control Sub-transmission Network.
- Distribution Management System (DMS) along with Distribution Automation (DA): to supervise and control 11 kV distribution network.
- Outage Management System (OMS): for complaint handling, outage management and crew management.
- Customer Information Service (SAP-CIS): unified juncture for consumer interaction and convey necessary information.

Due to all these continuous initiatives and technology adaptation, there is incessant improvement in Reliability Indices (SAIDI, SAIFI) since its inception in 2002. *SAIDI decreased from 8.6–2.68 h whereas SAIFI decreased from 6.5 to 2.5 in last 10 years* (Fig. 1).

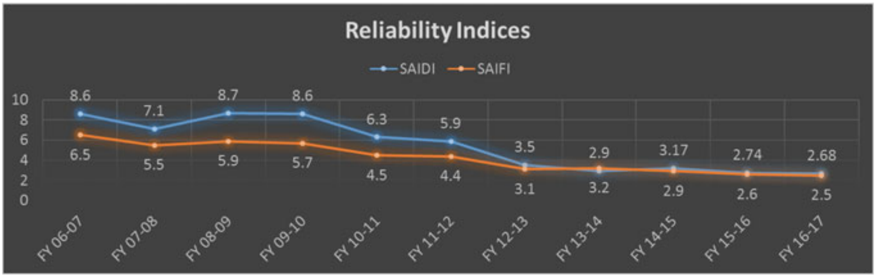

Fig. 1 Graph of reliability indices (SAIDI and SAIFI) of TATA POWER-DDL

2 Tata Power-DDL Challenge

Although TATA POWER-DDL's performance is going high, but due to increase in delicate electrical appliances, inclusion of Distributed Energy Resource like roof top solar plant and growth in Electrical Vehicles, consumer as well as regulators raise their bar of expectation. To meet their further expectation TATA POWER-DDL has stride toward Smart Grid technology like Smart Meters, Automatic Demand Response (ADR), Battery Energy Storage System (BESS) and Field Force Automation (FFA). These evolving technologies increase volume of data to be managed and visualized. Existing Technology like SCADA, DMS and OMS can handle and analyze limited data and unable to respond on new and relevant data coming from both grid sensors and consumers smart meters effectively. These applications are not capable of providing required level of reliability and safety to this emerging smart electric network. Thus, requirement of more advanced tool arises which are capable to organizes and analyses the gigantic volumes of proximate real-time complex data and integrate existing technologies into a unified platform for better network, outage and crew management. This study will describe how reliability and consumer satisfaction will improve in reference to the above stated challenges through Advanced Distribution Management System (ADMS).

Tata Power Delhi Distribution Limited is the first utility in the world to implement ADMS at such an extent with total integration of all the system in the utility, i.e. GIS, SAP, MWM/FFA, AMI etc. (Fig. 2).

3 Methodology

ADMS is an integrated platform with advanced monitoring application for better analysis and improved supervision and control of enormous real time electrical data (Fig. 3).

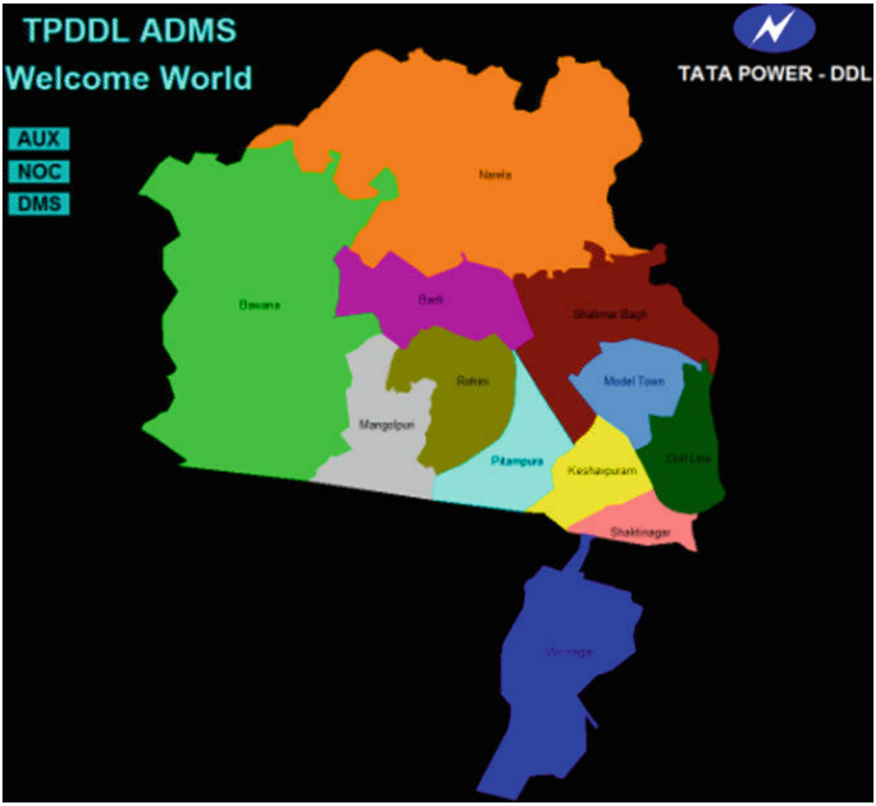

Fig. 2 TATA POWER-DDL world of ADMS

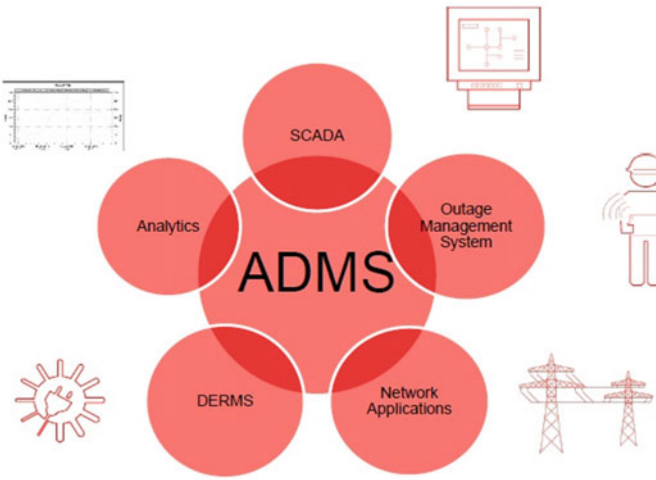

Fig. 3 Unified Platform with one User Interface for SCADA-EMS-DMS-OMS

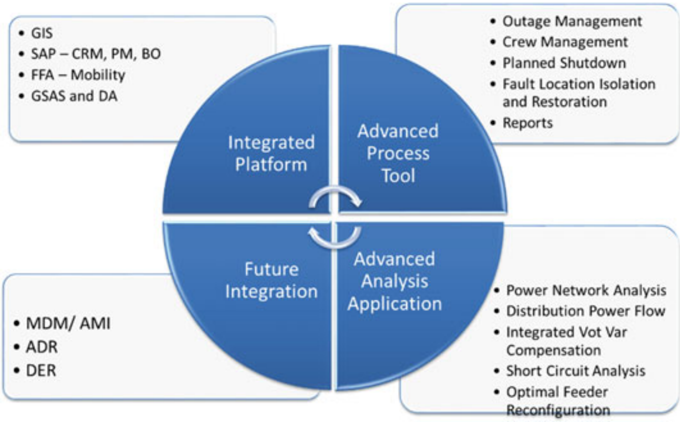

Fig. 4 Overview of ADMS

ADMS has capability to interface with new smart grid elements like Smart Meters technologies, ADR, DER and FFA etc. It is equipped with improved analysis and planning tools which provides better monitoring, effective network management, improved outage planning, proficient outage and crew management. These advanced applications help in maintaining network availability, power quality, reducing outage duration and ensuring better consumer satisfaction (Fig. 4).

4 Effective Network Management

At present, DMS and OMS are different platform properly integrated with each other and maintaining their own network at their end. Due to this reason at some time there is mismatch in both network. Hence network update in DMS, not properly update consumer supply in OMS. But now a single platform, ADMS will serve purpose of DMS and OMS and ADMS is well integrated with GIS. As network is updated in GIS the same will be updated in ADMS. So, network will be updated along with consumers as per actual site condition. In this way supply status of actual consumer will be updated in case of any outage which improve consumer satisfaction. Hence, ADMS provides an efficient visual interactive work environment that integrates all information source on a common real time workspace which helps in accurate estimation of consumer affected and extend of interruption as all work is done on a common GIS based platform and hence maintaining integrity of network.

5 Ensuring Availability

Power and network availability may increase by reducing either number of outages or outage duration through rapid restoration technique. ADMS is decorated with advanced application which will help in fast restoration of distribution network after tripping and assist in creating switching plan of any outage to reduce number of affected consumer and ensuring safe operation. These smart applications provide:

- *Restoring consumer faster*
- *Preventing Equipment Damage*
- *Improving Quality of Power Supply*
- *Effective use of field crews.*

5.1 Automated Power Restoration System (APRS)

APRS is an algorithmic approach for Fault Detection, Isolation and Restoration (FDIR). APRS uses real time data from network to locate fault. It is capable of executing a sequence of switching actions or can commend the same to isolate the fault and restore power to rest of the healthy network and consumers as many as possible. When a fault occurs on the network and an APRS automation program is invoked, the following occurs:

Fault Verification: A downstream trace starts from the tripped device to verify the fault.

Fault Location: The location of the fault is determined based on information provided by telemetered Fault Passage Indicators (FPI).

Fault Switching: Switching actions are created or executed to squeeze the extent of the fault in following way:

- *Isolate upstream then restore upstream by closing the tripped device.*
- *Isolate downstream, then attempt to restore each downstream outage by shifting consumers to neighbouring feeder.*

5.2 Switching Advisor (SA)

SA simplifies the creation of switching plans in either control or advisory mode. It allows you to select from one or more recommended switching actions and subsequently creates a work package with the proposed switching operations. It produces switching steps once a fault has been detected, using either DA and/or manual switches. The switching steps can result in the reduction of the fault area or in the proposal of alternative, manual restoration options to the Control Centre Engineer.

- *Proposing switching steps enabling us to reduce the affected area of network and to restore supply to consumer remaining off by 'squeezing' the fault.*
- *Proposing switching operations that include steps to isolate and earth the area of network to allow a permit to work to be issued.*

Beside this SA can also be used to propose a set of switching operations to maintain supply to customers in case of a planned outages. It creates a work package with proposed switching operations which can give confidence to the Control Centre Engineer that switching will not damage the network or violate any limits.

- *Maintaining supply to as many customers as possible during planned outages.*
- *Proposing switching steps to isolate and earth equipment. It also helps to create restoration switching plan once the required scheduled job has been completed.*

These smart switching functionalities will help us in maintaining power and network availability by reducing consumer interruption and subsiding outage duration. Hence reliability will be improved which ultimately results in improved consumer satisfaction (Fig. 5).

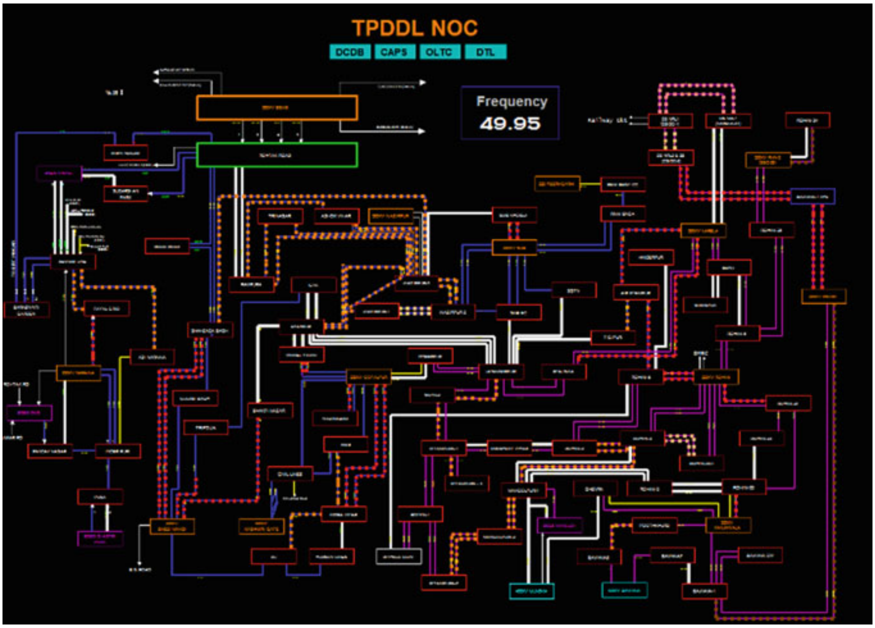

Fig. 5 TATA POWER-DDL NOC world of ADMS for fast switching operations

6 Ensuring Quality

ADMS is equipped with such applications which perform desired functions for maintaining quality of power supply like voltage magnitude, voltage balance, power factor (pf) etc.

Integrated Volt/VAR Control (IVVC): IVVC enable us to find an optimized set of switching recommendations for operation of Capacitor Banks and On Load Tap Changers (OLTC) integrated in our system to achieve greater efficiency and desired operational parameters. During optimization, the application examines the selected section of the network or complete network, taking into account device states, operational constraints and expected load conditions in order to achieve a certain objective. Multiple objective functions can also be added with different weightage so that algorithm tries to satisfy each criterion according to its relative weighting. Following are the different objective functions:

Flatten Voltage: This objective function optimizes voltage and reactive power within normal or emergency voltage limits to minimize the voltage drop in the circuit.

Maximize Power Factor: This objective function optimizes the voltage and reactive power within normal or emergency voltage limits to achieve power factor to set point.

Optimize Reactive Power: This objective function optimizes reactive power to pre-set value. This function is also capable to minimize the reactive power, maximize inductive reactive power and maximize capacitive reactive power.

Optimize Real Power: This objective function optimize real power to pre-set value. This function is also capable to minimize and maximize real power.

6.1 Optimal Feeder Reconfiguration (OFR)

OFR enables to perform analysis of the network, or specific areas of the network, to identify the optimal positioning of Normal Open Points (NOP) in order to achieve voltage regulation or reduce technical losses. Reduction in technical loss may reduce power requirement of utility which transform into reduction in total Power Purchase Cost and hence helpful in Tariff Control. This functionality can be based on combinations of the following—Transformer Utilization, Feeder Load and Consumer per feeders.

Improving Transformer and Feeder utilization means network can be utilized in more effective manner and additional consumers can be served without any additional capital investment in network infrastructure.

Under fault conditions, a balanced network presents more options for reconfiguration, potentially with less switching. Also, NOP positioning can be arranged to balance customer counts so that the Customer Minutes Interruption (CMI) under fault conditions is minimized.

These smart applications will help us to provide power to our consumer within specified limit of power quality parameter like voltage, power factor etc. and also help to improve CMI. Hence these all will collectively improve consumer satisfaction.

Enhancing Satisfaction: Consumers are the end user of electricity and hence last mile in any Distribution Network. That is why it is the prime responsibility of every distribution utility to improve consumer delight. All the initiatives, technology adoption and process improvement are done with keeping it in their mind. So, ADMS also has some advanced and progressive feature to improve consumer satisfaction.

6.2 Outage Prediction

For faster identification of fault, intelligent Outage Prediction logics are set in ADMS. ADMS consist of Call Grouping Engine which processes calls by firstly analyzing the LV network, then, if it cannot locate a tripped device then HV network is analyzed. The prediction of an open device is determined by comparing the number of *no supply call* downstream of the device, against the prediction trigger count of the device, after taking into consideration the timestamps associated with each calls. Protective devices are considered while Escalating and Deescalating Prediction. Besides Customer Calls, Meter Events and SCADA status are also used to accurately predict and update the scope of an outage. Field crew can directly be dispatched to the predicted device. This will result in saving time of finding fault and can help in minimizing repairing and restoration time. Estimated Restoration Time (ETR) are also calculated automatically based on current conditions including type of fault, travel times and time-of-day and updated as crew are allocated and arrive on-site.

ADMS also helps to manage power outages on their networks by providing timely and updated information to consumers. As switching or device operation is confirmed, the system automatically updates power status of the consumer and the information is recorded for analysis and shared with the Call Centre. ADMS is also capable of conveying information of schedule outages to their consumer some day ahead. Hence consumer will be well informed of their power outages, its severity along with expected time of restoration.

7 End to End Integration

7.1 Adms-AMI

The AMI Interface allows the ADMS system to obtain meter data by interrogating the AMI system using the MultiSpeak protocol. The user can request readings from any meter and display the data on-demand in the ADMS map. Users can also define schedules for the ADMS system to automatically interrogate the AMI system for specific meter data. The received data is stored in the analog points. This data can be used by other applications such as voltage readings for voltage reduction algorithms.

7.2 Adms-AVL

AVL is an interface that enables the location of GPS transponder equipped vehicles to be displayed on a map within ADMS. The location of the vehicle is updated real-time within ADMS so the user can see the actual location of the vehicle on the system map.

7.3 Adms-MWM

This interface provides the ability to connect to a third-party Mobile Workforce Management System. With this interface, operators can track the status of jobs and crews related to outage cases. Utilities also have the option of dispatching jobs to an external MWMS; the MWMS would track jobs and crew availability and update the OMS with changes.

7.4 Adms-GIS

This interface provides the ability to push the network from Geographical Information System (GIS) to ADMS based on Common Information Model (IEC Standard model to exchange data) (Fig. 6).

Fig. 6 TATA Power-DDL ADMS CIM World view

7.5 *Adms-DER*

It offer technological solutions to integrate:

- Increasing penetration of distributed energy resources (DER), including distributed generation, distributed storage, demand response, and Micro-grids
- New regulatory regimes
- Heightened physical and cyber security threats
- Aging utility infrastructure and workforce
- Potential and actual structural changes to the distribution business model.

8 Observation

With adaption to Smart Grid Technologies, Tata Power-DDL is moving forward to become a SMARTER DISCOM by adding valuable infrastructure, enhancing consumer services and improve efficiency through implementing ADMS. ADMS is a leading edge technology, packed with progressive application which will help in improving reliability, ensuring power quality and achieving consumer delight.

APRS: helps to reduce outage duration.

Switching Advisor: helps to squeeze the extent of the fault and reduce customer outage.

IVVC: helps to optimize voltage and reactive power to improve quality of power delivered.

OFR: helps to optimize NOP to reduce technical loss, improve voltage profile and enhance equipment utilization.

Outage Prediction: helps to subside fault repair time and improved outage management.

ADMS also helps in provide necessary information of power status to their consumer.

9 Conclusion

Amid stride to achieve vision of Smarter DISCOM, ADMS is a technological milestone which helps in improving network reliability by reducing impact and duration of scheduled and unscheduled outages, increase operational productivity by ensuring operational safety and enhancing consumer satisfaction by updating consumer of its power outage and other necessary information timely. Hence ADMS is an application which will help TATA POWER-DDL to suffice all requirement to face upcoming challenges due to integration of smart grid technology and to meet fore coming expectation of their consumers as well as regulators.

References

1. Power On Advantage—Advanced Distribution Management by GE Grid Solutions
2. Article on Advanced Distribution Management System by Artur R. Avazov, Liubov A. Sobinova, National Research Tomsk Polytechnic University
3. White paper on Advanced Distribution Management by Oracle Utilities
4. IEEE Xplorer. http://ieeexplorer.ieee.org/

Damage and Exposure Prevention of Energy Infrastructure Through Strategies in PEER: Evolving Trends for Efficiency, Reliability, and Resiliency

Ishaq Sulthan

Abstract Power is a basic necessity for every human being, if lost or interrupted causes a huge discomfort. Often these interruptions are caused due to external damages and exposure to the environment. In recent times, cities all over the world are facing big challenges due to climate change causing unprecedented rainfall/hurricane leading to flood. During such catastrophic events, communication networks and power supply is essential to keep oneself protected, safe and reach-out for emergency support. Apart from these extreme weather conditions, interruption in grid network is also happening due to tree contact, animal contact, accident due to vehicles or human interference and fire. All these events can cause a significant human & revenue loss if unprepared. Under this circumstances, it is critical we build resilient & reliable grid systems that help us during natural disaster, human error & threats. The damage that power interruption events caused from a practical and economic standpoint is a key concern for customers. Measuring, reporting, trending, and benchmarking these metrics will assist with identifying poor performance and provide the justification for investment to reduce sustained interruptions and improve reliability. Performance Excellence in Electricity Renewal (PEER) is an effective framework that looks comprehensively on Reliability & Resiliency with specific focus towards damage and exposure prevention. The credit implies on the project to focus on the identification of external threats and measures to mitigate them. It also specifically mention about the hardening of power systems from floods and storms, references to be considered while designing or retrofit, thus reducing the likelihood of equipment failures due to any external & physical threats.

Keywords Exrternal damages · Natural disaster · Power system hardening · Reliability · Safety · Threats

I. Sulthan (✉)
GBCI, New Delhi, India
e-mail: isulthan@gbci.org

© Springer Nature Singapore Pte Ltd. 2020

R. K. Pillai et al. (eds.), *ISGW 2018 Compendium of Technical Papers*,
Lecture Notes in Electrical Engineering 580,
https://doi.org/10.1007/978-981-32-9119-5_2

1 Introduction

Worldwide, cities and communities are utilizing new and innovative technology to address natural and man-made threats. Often these energy infrastructure is tested by blackouts, natural disasters, and increasingly cyber-threats such as the Hurricane Harvey & Irma that damaged the US grid infrastructure in 2017 and in December 2015 attack that took down the Ukraine power grid. While there have been significant strides in some respects, grid inefficiencies and risks are costly, having multiplier effect and likely to increase in future. According to NOAA's National Centers for Environmental Information, the United States has suffered 212 weather and climate disasters since 1980 that have cost more than $1 billion, totaling $1.2 trillion [1]. Power interruptions cost European Union businesses €150 billion each year [2]. In India, at Tamilnadu, during Vardah cyclone in 2016 the state utility Tamilnadu Generation and Distribution Corporation (TANGEDCO) has lost 10,000 electric poles and 800 transformers got damaged causing a loss of more than 1000 crores [3]. Apart from these natural disasters causing damages to the energy infrastructure, there are other threats such as tree falling, animal or vegetation intrusion, human interference causing outages locally. A recent EU study found that €4 billion could be saved annually from using smart grids that includes right from Advanced Metering Infrastructure (AMI) capability to power system hardening techniques.

This paper talks about how by leveraging the PEER (Performance Excellence in Electricity Renewal)—Damage and Exposure Prevention strategies these challenges can be better planned and managed across campuses, communities and cities. PEER is a certification program that measures and improves power system performance and electricity delivery systems.

The comprehensive credit based programme is classified under 4 key categories;

- Reliability & Resiliency
- Energy Efficiency and Environment
- Operations, Management & Safety
- Grid Services.

2 Common Risks and Threats

Common risks and infrequent threats are conditions that occurred in historical data disrupting the quality of electricity delivery such as voltage swings, faulted lines or blown fuse caused due to tree or animal contact or human interference etc. These types of events can realistically be expected to occur periodically in the region where the project grid is located; for example cyclones are historically recorded in

Balasore, Nellore but not in Hyderabad. Hence, by doing this assessment, the grid operator can take meaningful decisions to design or make improvements to modernize the electricity grid.

PEER defines the following as common risks and threats that can affect the reliability performance of a grid infrastructure.

- Supply interruptions—originating from;
  - Tree or branch interference
  - Vines causing short circuits
- Unintentional damage to equipment—including damage from;
  - Animal interference
  - Traffic accidents
  - Unintended public exposure
- Extreme weather—depending on the location of the project grid this may include;
  - Flooding/Rainfall
  - Windstorms, Sandstorms, Ice storms.
  - Earthquakes.

The key objective is to support projects with considerations for common risks and threats, and raise awareness of strategies and measures that can be used to improve reliability by reducing the damages to the grid infrastructure.

3 Damage and Exposure Prevention Strategies

Projects around the world are often looking for advanced technologies and innovative solutions to mitigate common risks and threats through prevention of external damages and exposure to the environment. PEER program proposes the following techniques or strategies to prevent from external damages and threats;

Option 1. External Damage Prevention

A. **Prevention from Tree Contact**: It is observed that relatively high percentage of cable failures were caused by tree fall in bad weather. Tree management near distribution lines is an important adaptation action needed to reduce risks of power distribution system outages. The objective here is to prevention of cables and power system from tree contact.

Tree damage can be organized into five categories:

- Broken branches
- Trunk bending
- Splitting of main or co-dominant stems

- Complete trunk failure
- Tipping or up-rooting.

Following are the two prevention techniques of cables and power system from tree contact;

1. *Up gradation of overhead distribution lines*—Upgrading of overhead distribution equipment, with the aim of making the system more resilient against damage downed trees and limbs. Redesigning wires to provide better protection from falling tree limbs, and to detach more easily when force on the wire is more extreme to reduce the likelihood of damage to poles and other pole-top equipment. Creating greater tree clearances around distribution facilities near substations and critical infrastructure.
2. *Hazard Tree program and vegetation management*—Identify trees that are tall enough to contact the overhead distribution system and are also dead, declining, diseased, or otherwise structurally unsound. Some of the important programs in hazard tree management program include;
    - Designating responsible individuals,
    - Identifying and prioritizing the sites to be examined,
    - Performing and documenting the inspection,
    - Performing the necessary actions to reduce the hazards (Vegetation management),
    - Maintaining the records of inspection & actions taken,
    - Recording tree failures. The program should be compatible with available resources (personnel and funding).

B. **Prevention from Animal/Bird Contact:** Animals such as squirrels and monkeys and birds such as crow, sparrow are probably one of the most causes of distribution faults. Below are the list of problems caused in the grid infrastructure by animals/birds;

- Animals in substations cause a variety of problems, such as faults, which can result in power outages, reduced equipment life, or severely damaged equipment.
- Squirrels, raccoons, snakes and other creatures that climb fences, structures and equipment may eventually come into contact with energized parts of equipment.
- Rodents chewing through power and control cable insulation can also cause outages and damage.
- Bird build nests in substation structures and equipment.
- Some birds have wing spans that can bridge phase-to-phase distance and cause an outage.
- Bird droppings can also be a major problem.

Some of the mitigating methods are;

- **Fence barriers**—To deny animals access at the fence line for an outdoor substation requires consideration of possible access paths over, through, and under the fence [4].
- **Fake predatory animals**—Plastic owls, snakes, falcons or other objects can be placed conspicuously in the substation structure or on top of an enclosure.
- **Disturbing noises**—Various types of disturbing noises can be generated to drive off animals. They consist of ultrasonic, loud, or danger signal noises.
- **Chemical repellents**—Chemical repellents and additives can be used to treat the food supply, or as baits in traps to kill animals if they enter or live within the substation.
- **Perching and climbing deterrents**—Anti-perching features or conductor covers to prevent birds from perching, nesting, and shorting exposed overheard conductors. A common deterrent involves the use of a sticky gel. This gel can be applied as a deterrent, to surfaces where birds perch such as structures, incoming wires, and guy wires.
- **Screened nesting locations**—Deterrence of birds and other animals from the general area can be accomplished if access to the preferred nesting sites within the substation is denied.

C. **Prevention from Human interference**: Substations and transmission lines that are close to the highway or on the adjacent to pathway is often prone to human attacks or vehicle accidents.
Design requirements should include damage exposure prevention and protection to all potentially exposed major/Critical equipment such as but not limited to

- Fencing around the structure
- Pad-mounted equipment along roadways, walkways, and bicycle paths
- Transformers (Indoor and Outdoor Type)
- Construction of wall around the structure with secured access.

D. **Prevention from Extreme Weather conditions:** Power outages due to severe weather events (floods, heavy winds, earthquakes, tropical cyclones) has increased over the last decade, many utilities/campus projects sought to reduce the weather related outages by "hardening" the systems to flooding, heavy winds, and earthquakes by making the major electrical equipment less susceptible to damage. Considering the power system hardening strategies during the initial stages of project can significantly contribute in reducing the total operational and damage cost incurred from severe weather events.

PEER propose following design considerations and/or infrastructure to harden power systems against flooding, storms, and other extreme events, to maintain continuous availability of power supply;

1. **Flood plain avoidance** – Implement one of the following strategies to prevent damage to electrical equipment and assets (e.g., substations, diesel gensets, transformers, OH cables) and ancillary equipment (e.g., pumps, compressors), based on a 100-year flood mark or flood map. Protect stored fuel to meet or exceed the requirements set by the authority having jurisdiction.

   - Strategy 1: Build a permanent storm water drainage system to protect critical power assets from inundation.
   - Strategy 2: Install a standalone pump to pump water from low-lying areas around the electrical systems. The pump should be operable in the absence of power supply.
   - Strategy 3: Permanently relocate or increase the height of critical power assets in the flood-prone area as per your local flood zone map.

2. **Storm protection**—Ensure that the outdoor equipment can withstand three-second wind gusts up to 140 mph or equivalent. This may include electric poles, substations, transformers and over-head line.
3. **Seismic protection**—Have in place seismic restraint–certified equipment for critical electrical systems and/or install a seismic restraint structural support for critical electrical systems, based on the seismic zone. The critical electrical system would include substation, Transformers, Poles and other infrastructure depending on the importance of the project.

   Apart from this, NFPA 1600 defines general criteria for organizations to use for developing disaster management programs [5] that focus on the safety measures to be considered during normal and emergency conditions like an extreme events.

E. **Undergrounding**—One of the old strategy of power system hardening is Undergrounding. Placing electrical cables underground, eliminates their susceptibility to heavy winds, ice and lightning damage. In many countries, undergrounding has been proposed as a solution for hardening the transmission and distribution system.

The graph below derived from European report CEER Benchmarking Report 5.1 [6]—CoS demonstrates that undergrounding has a significant positive impact on reducing system outages (Fig. 1).

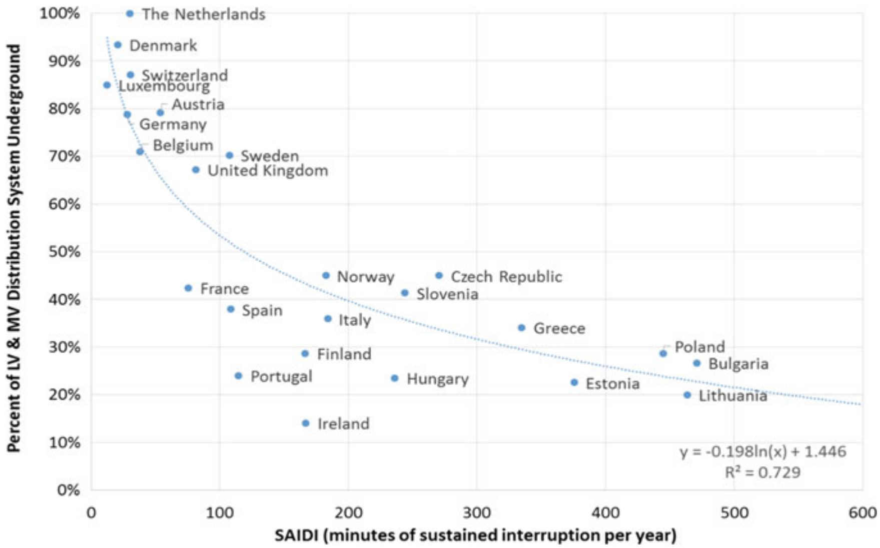

Fig. 1 Showing the reduced SAIDI based on increased underground cabling across Europe

4 Conclusion

Failures of network components could significantly affect the reliability of power systems. Component failures are caused by different factors. Analysis of the failure causes has a practical value since the knowledge of failure causes could help power utilities to take remedial actions and determine appropriate method for failure reduction. Damage and exposure prevention design considerations and prevention strategies reduce the likelihood of equipment failures due to external physical and environmental threats.

Over a period of 2003–2012, weather-related outages are estimated to have cost the U.S. economy an inflation-adjusted annual average of $18 billion to $33 billion [7]. The costs of outages take various forms including lost output and wages, spoiled inventory, delayed production, inconvenience and damage to the electric grid. Continued investment in grid modernization and resilience will mitigate these costs over time—saving the economy billions of dollars and reducing the hardship experienced by millions of Americans when extreme weather strikes. Thus, in a current scenario power system hardening and prevent from external damages has become crucial for both developed and developing countries like India which has seen quite a few weather-related outages in recent years. Modernizing these grid infrastructure to make them resilient will be the need of hour and through PEER strategies and techniques explained in this paper Cities, Communities and buildings can better prevent from external damages & risks.