



Ain Shams University  
Faculty of Engineering  
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## Contingency Re-planning in Smart Distribution Systems

Thesis Submitted by

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## **Statement**

This Thesis is submitted to Ain Shams University in partial fulfillment of the requirements for Ph.D. degree in Electric Power Engineering.

The work included in this thesis has been performed by the author at the department of Electric Power and Machines, in the Faculty of Engineering, Ain Shams University. No part of this thesis has been submitted for a degree or a qualification at any other university or institution.

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## **Acknowledgments and Dedication**

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Hatem Zaki  
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## **Abstract**

This dissertation discusses changing the Distribution System (DS) topology and re-planning it under Smart Grid (SG) framework. The purpose of this research work is to resolve some of the problems required to change the topology of the DS aiming towards re-planning the DS from its existing topology to the open loop topology as the foundation of the DS modernization techniques. As part of the SG framework, Contingency re-planning has been considered using redevelopment of the mathematical model including development of a new Contingency Index (CONDEX) in addition to the Cost Index (COSTINDEX). A hierarchical SG framework is presented with emphasis on the building foundation which is the planning aspect of SGs. Multiple topologies are presented with a comparison of the advantage and the disadvantage of each topology.

The mathematical model has been rebuilt with a new combined multi-objective formula, minimizing the system expansion Capital Costs, Operations and Maintenance (OM) costs and achieving the best combined performance measure consisting of a combination of Reliability, Resiliency and Vulnerability. A new practical weighted combined system contingency index is applied and tested to be used by utilities replacing the common simple reliability indices. The new model uses the application of multi-objective optimization utilizing integer design variables, which include a combination of multiple logical and technical constraints to provide the best description of the real existing system constraints.

In addition to the new CONDEX, new iterative algorithms and approaches are proposed to form the constraints of the problem. Several algorithms are presented, discussed and compared aiming to simplify the problem and represent real life systems. Some constraint algorithms are discussed in details covering common techniques and proposing new techniques for the same goal.

To apply the new proposed SG mathematical model, three basic planning problems are being presented and resolved. These problems are: The Distribution System Expansion (DSE) Problem, the Switch Allocation (SA) Problem and the Distribution System Reconfiguration (DSR) Problem. An overview study of common DS protection strategy aspects is also provided with some highlights of new industry trends in the field of open loop high speed protection systems suitable for modern DSs.

The proposed SG model was applied to multiple standard and modified DS test cases including a system from real life applications. Results obtained from the application of the SG model to the three problems on standard DSs, demonstrate improvements in the objectives satisfying all constraints and utilizing the proposed model including the proposed new constraint algorithms.

The solution technique followed in solving the stated three problems is the Genetic Algorithm. This algorithm was chosen due to its readiness with default parameters within the solution software. The dissertation also provides conclusions and recommendations for future work.

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## Abbreviations

|            |   |
|------------|---|
| BMS        | Building Management System  |
| CBR        | Customer Based Reliability  |
| CELID      | Customers Experiencing Lengthy Interruption Durations               |
| CEMI       | Customers Experiencing Multiple Interruptions                       |
| CONDEX     | Contingency Index   |
| COSTINDEX  | Cost Index  |
| DG         | Distributed Generation  |
| DoE        | Department of Energy  |
| DS         | Distribution Systems  |
| DSE        | Distribution System Expansion                                       |
| DSR        | Distribution System Reconfiguration                                 |
| ENS (EENS) | Energy Not Served (Expected Energy Not Served)                      |
| EV         | Electric Vehicle  |
| FCL        | Fault Current Limiter   |
| GA (MOGA)  | Genetic Algorithm (Multi-Objective Genetic Algorithm)               |
| IT         | Information Technology  |
| OM (OMA)   | Operation and Maintenance (operating, Maintenance & Administrative) |
| PDGA       | Planar/Dual Graph Algorithm   |
| PEV        | Plug-in Electric Vehicle  |
| PHEV       | Plug-in Hybrid Electric Vehicle                                     |
| PV         | Photo Voltaic   |
| SA         | Switch Allocation   |
| SAIDI      | System Average Interruption Duration Index                          |
| SAIFI      | System Average Interruption Frequency Index                         |
| SG         | Smart Grid  |
| SRI        | System Resiliency Index   |
| SVI        | System Vulnerability Index  |
| TOU        | Time of Use   |
| URI        | Unified Reliability Index   |
| VVO        | Volt Var Optimization   |