Report

Power System Lab- IIT Madras
K.S.Swarup

2017 - 2018

Introduction

The Power Systems lab at IIT Madras was involved in research related to:

- Power System Protection
- Power System Operation and Planning
- Smart Grids
- Power System stability and controls
- Automation

in the year 2017-18. Following is the brief discussion of the works that were selected for publication in last year.

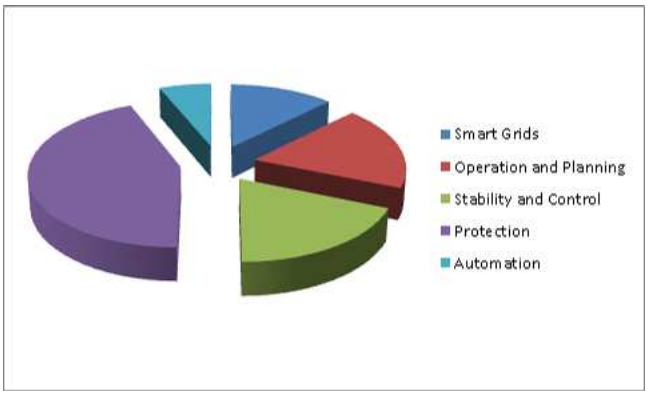

Figure 1: Publication- Are wise breakup

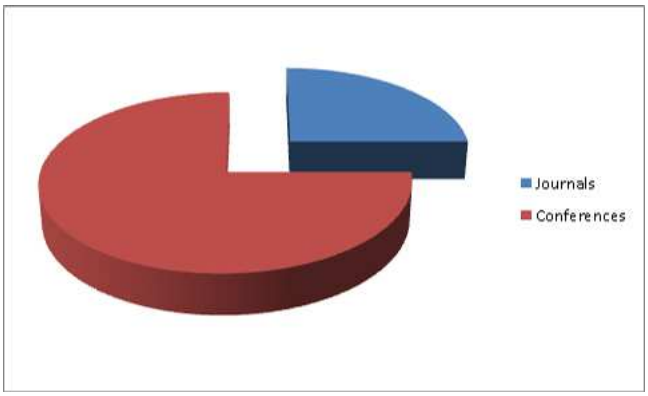

Figure 2: Publication- (Journal vs Conferences)

Table 1: Publications 2017-18

Area	Journals	Conferences
Smart Grids	1	1
Operation and Planning	-	3
Stability and Controls	2	1
Protection	1	6
Automation	-	1
Total	4	12

1 Model predictive control approach for frequency and voltage control of standalone micro-grid

IET Generation, Transmission Distribution Journal

Vidyasagar and K.S.Swarup

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The frequency and voltage control of a standalone micro-grid with synchronous generator-based distributed generator and electronically interfaced generator is discussed. A centralised linear model predictive controller is employed. The controller design is based on the state space model of the micro-grid. To decrease the number of optimising

variables and calculation time of optimal control trajectory, the design of the controller is realised with the help of orthonormal Laguerre polynomials. The numerical instabilities that arise during implementation and the possible ways to overcome them are discussed. The impact of different generator constraints on the controller operation is discussed. Formulation of the micro-grid model and identifying the appropriate inputs and outputs to the controller is discussed in detail with the help of an eight bus micro-grid.

2 Mathematical morphology- based islanding detection for distributed generation

IET Generation, Transmission Distribution Journal

Aneesa Farhan M A and K.S.Swarup

Aneesa Farha MA and K.S.Swarup are with Department of Electrical Engineering, Indian Institute of Technology Madras

The study focuses on a novel strategy for microgrid protection based on mathematical morphology. Mathematical morphology is a time-domain signal processing tool that could be used for accurate and reliable signal component extraction. In this study, a class of non-linear multiresolution decomposition scheme called morphological Haar wavelet (MHW) is used for detection of faults in microgrid. The proposed method uses the detail signal of MHW obtained after prediction lifting for fault detection and faulty phase selection. Accordingly, current retrieved from both ends of the feeder are processed through MHW after prediction lifting scheme to obtain the detail signals. The detail signal difference and their norms are calculated to obtain a primary protection scheme for the feeder. Also the same scheme was investigated as backup protection for very low fault resistances by taking the currents of the adjacent feeders. The performance of proposed technique was evaluated for islanded and grid connected mode of operation, for different network topologies, i.e. radial and looped system for various fault and non- fault disturbances.

3 Coordinated Reactive Power and Crow bar Control for DFIG based Wind Turbines for Power Oscillation Damping

Wind Energy Journal, Sage Pulications

Likin Simon , Jayashri Ravishankar and K Shanti Swarup

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The Fault Ride Through (FRT) capability and fast controller action makes Doubly Fed Induction Generator (DFIG) based Wind Energy Conversion System (WECS) to actively participate in power oscillation damping (POD). This paper describes a coordinated reactive power control from Grid Side Converter (GSC) along with active crowbar scheme for DFIG which can actively participate in the power oscillation damping, and thus improving the transient stability issues. For a reactive power oscillation damping (Q POD), it is essential that the phase of the modulated output is tightly controlled to achive a positive damping. Detailed 3 generator 8 bus WSCC system is modeled in PSCAD/EMTDC with the generator dynamics. The dynamics in power flows generator rotor speeds and voltages are analyzed followed by a three phase fault in the power system. A set of comprehensive case studies are performed to verify the proposed control scheme.

The advantage of the proposed control scheme is that no dedicated communication devices or any other additional hardware equipments are required for the control. The control schemes associated with the back to back converters and crowbar converter is slightly rearranged in such a way that a compensating electromagnetic torque is developed in the machine to damp out the power oscillations.

4 A Review of Uncertainty Handling Techniques in Smart Grid

International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems Vol. 26, No. 3 (2018) 345–378 c World Scientific Publishing Company DOI: 10.1142/S0218488518500186

Pranjal Verma, Dipti Srinivasan, K.S.Swarup, Rahul Mehta

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This paper is a review of uncertainty modeling techniques used in smart grid studies. The literature dealing with uncertainty from various sources in smart grid is analyzed and presented. In a modern power grid, the risk may arise due to different reasons; intermittent renewable energy sources, uncertain consumer reactions on demand response, driving patterns of electric vehicles, etc. The paper has two objectives. First is to bring out the trends in uncertainty handling techniques used in electrical power system problems, and second to introduce the scope of new risk processing techniques with the perspective of recent smart grid issues.

The main contributions of this paper are as follows: • A new classification based on smart grid applications for uncertainty handling techniques. • Identifying the scope of improved or new uncertainty handling techniques suitable for modeling uncertain parameters in smart grid.

5 Computational Intelligence Techniques in Smart grid planning and operation: A Survey

ISGT Asia 2018, Sinagpore

Pranjal Verma, Krishnendu Sanyal, Dipti Srinivasan, K.S Swarup, and R.Mehta

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The Smart Grids are the future vision of the electric power system with integrated communication, protection, control and sensing technologies. With the introduction of new technologies which constitute the smart grid like demand response, demand side management, electric vehicles, energy storage systems, distributed energy resources, integration of renewable energy resources, and forecasting methods like artificial neural networks, deep learning methods etc, the scope of planning and operation of a smart grid has broadened. The new technologies bring in the need for better tools for solving the planning and operation problems. This paper aims to provide a survey of the works related to some of the smart grid components and classifies the

works based on the computational intelligence tools used in solving the planning or operation problem.

The main contribution of this paper is classifying the existing literature in each smart grid technology according to the computational intelligence tool.

6 Single-Stage vs Multi-Stage Transmission Expansion Planning in Electricity Markets: An MILP approach

ISGT Asia 2018, Sinagpore

Pranjal Verma, Anoop V.E, Aneesa Farhan, K.S. Swarup, R. Mehta, and Dipti Srinivasan

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This paper analyses the benefit of a multi-stage transmission expansion planning (TEP) over single stage TEP. The paper establishes the conditions (load growth and interest rate) under which the two formulations are equivalent, and when a multi-stage TEP formulation could lead to a better solution. The paper answers an important question of how the planning span shall be divided into stages when going for a multi-stage TEP. The paper further analyses the effect of high peak to average load ratio (PAR) in a multi-stage TEP. The single-stage and multi-stage TEP problems are formulated to minimize the total investment and operation cost over the planning period. The operating cost is calculated by dispatching the generators and loads in a double sided auction market where the supply and demand bids are assumed to be fixed over the planning period. The TEP problem has a mixed integer linear programming (MILP) formulation and is tested on 6 bus Garver System implemented in GAMS. The main contributions of the paper are following:

- Identify the parameters that make multi-stage TEP more optimal over a single-stage TEP.
- Paper proposes empirical rules on segmentation of planning horizon into stages for optimal results with lowest possible stages.

- Show the optimality of a multi-year TEP with lower resolution of stages.

7 Transient Modeling and Control of DFIG with Fault Ride Through Capability

ISGT Asia 2018, Sinagpore

Likin Simon, Naina P M, and Shanti Swarup

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The scarcity in the electrical power generation and huge demand of power promotes more renewable energy integration to the grid. This paper proposes a solution for Fault/Low Voltage Ride through (LVRT) problem with dynamic crowbar operation for grid connected Doubly Fed Induction Generator (DFIG) based Wind Energy Conversion Systems (WECS). Stator and rotor equations are developed in dq frame which makes possible to control active and reactive powers independently. Crowbar resister is connected at the rotor terminals to limit the rotor currents to protect the converters during low voltage or fault conditions. During abnormal condition, the crow bar connected in series with the rotor windings dissipate the rotor energy and limit the converter currents. This paper proposes an adaptive crowbar resistance which can dynamically change the resistance value to control the amount of rotor power to be dissipated. A set of comprehensive simulation case studies are done to verify the proposed control strategy.

This paper proposes a dynamic crowbar resistance control where variable resistances are connected to rotor side without disturbing the GSC triggering circuit. Adequate amount os energy is dissipated in the crowbar resistance to prevent the rotor over speeding and converters from over current. During the time of fault, depending on the rate of increase of rotor speed, the crowbar resistances are dynamically selected to dissipate the energy. This prevents the DC link over voltages, protects the converters from over current and GSC can provide reactive power support to the grid when it is mostly needed.

8 Impact of Active Network Management Scheme in Fault Protection Design and Network Operation for Is landed Power System

ISGT Asia 2018, Sinagpore

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The increased integration of Distributed Energy Resources (DER) and intelligent control technologies to distribution networks have succeeded in framing foundation for smart power grids. Design of protection systems and voltage regulation methodologies for an interactive smart grid will face new challenges with the introduction of new grid codes, active network management schemes and islanded operation. The active network management and optimal sizing of distributed sources shall change the operating point of the smart inverter-based DER in the islanded electric power system (EPS) continuously. This paper assesses the impact of such schemes on fault current magnitudes for various fault cases and voltage regulation at various nodes of an islanded EPS with distributed energy resources.

The key contributions of the paper are: • Using Smart Inverter to dispatch renewable energy based DERs. • Establish a relation between optimal sizing of DERs and proximity to the load growth centers. • Investigate the impact of active network management on fault scenarios

9 Islanding Detection using Mathematical Morphology for Distributed Generation

ISGT Europe 2017, Italy

Aneesa Farhan M A and K.S.Swarup

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The paper presents a novel method for islanding detection based on time domain, non linear signal processing tool called Mathematical Morphology. The method uses Multi-resolution morphological gradient (MMG) algorithm to operate on three phase voltages and currents at target DG location. The result of MMG algorithm is used

to compute norm of the three phase voltage and current. The ratio of these norms (voltage and current) are used to obtain a norm ratio index for each phase. Norm index for Islanding detection is obtained by summing the norm ratio index of each of the three phases. Norm index is found to be very effective in detecting island in distribution system with distributed generation integration.

This paper describes a time domain approach called mathematical morphology (MM) for islanding detection.

10 Optimal Tie Line Placement of Distribution System Incorporating Performance Based Rates

ICPS 2017, Pune

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In this paper optimal tie line placement problem is solved focusing on minimization of penalties incurred by Distribution System Operator(DSO) for not meeting reliability standards .A discrete function of penalty rate was taken which varies increasingly with interruption time .The risk profiles of each load was simulated by Monte Carlo simulation method considering failure outage data of the feeders and lateral transformers.A graph theory based distribution load flow has been conducted and optimal tie line location was found out by fundamental loop based algorithm

This paper includes formulation based on risk levels of various loads, the risk levels were obtained by time sequential Monte-Carlo simulation simulated in Python and C. An algorithm based on fundamental loop was used to find the optimal buses for tie line placement.

11 Detection, Localization and Fault Diagnosis Using PetriNets for Smart Power Distribution Grids

ICPS 2017, Pune

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Fault detection in novel distribution systems has been a big challenge with increasing distributed generation. Addition of non-linear devices has increased the rate of fault occurrence and thus a need to identify and rectify the fault with in a short interval. Inclusion of smart devices such as smart meters and PMU(s) can help a lot in reducing the fault detection time. Since most of the fault detection algorithms use iteration and a number of assumptions of the network topology, often the difference between the calculated fault distance and the real fault distance is huge. In the case of micro grid a single fault can result in more than one fault directions. Using petri nets can be of great use for fault detection as it has some major advantages. Petri nets don't use iterations and can precisely narrow down the fault depending upon the input data. A distribution network has been taken and simulated for both single and multiple fault instance. The algorithm was found to be simple and efficient. It can take information from protection device too which in aver all makes it a much more cost efficient method to challenge fault detection

The major advantage with the proposed approach is that we can use data even from bus protection or generator protection system and bot just fault recording devices. Thus it avoids the installation of fault recording devices in the entire network

12 Analysis of Network Topology Processor in Substation Level Networks

ICPS 2017, Pune

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The network topology processor is part of the power system analysis, the function of the network topology processor is to take the bus-section/switching device model of the power system network and use the data on the status of all the circuit breakers and switches in the power system network to build the bus/branch model for the given power system network. The output of the network topology processor is used in the further analysis of the power system network. The aim of this paper is to build and analyze the network topology program

algorithm described in the papers. The network topology processor program for the above algorithm is implemented in matlab and test case scenario is run on this built network topology processor program

13 Instantaneous Symmetrical Components Based Microgrid Interface Protection Relay

ICPS 2017, Pune

Anoop V Eluvathingal and K.S.Swarup

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In this paper, a new protection relay for interfacing microgrids with inverter-based sources to an active distribution network is proposed. The proposed relay algorithm is based on instantaneous symmetrical components. This protection scheme can address the protection issues in active distribution networks, caused by limited and variable fault current contribution from inverter based sources. The effectiveness of proposed method is analyzed by conducting simulation studies in the PSCAD/EMTDC software environment.

14 Modeling and Simulation of Virtual Power Plant in Energy Management System Applications

ICPS 2017, Pune

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The high penetration of renewable resources in the existing grid, increases the complexities of the grid. Nowadays, the integration of renewable resources became a big issue. These resources cannot participate in electricity markets because of their smaller size. The concept of virtual power plant (VPP) can enable the market participation of small generating units. The VPP can also provide ancillary

services like frequency support, reactive power support. This paper explains the VPP concept, the structure of VPP and also the market participation. An Energy Management algorithm for VPP is also explained. A small VPP model, consists of two distributed generation (DG) sources and two controllable loads, is demonstrated in MATLAB-SIMULINK. In addition, the current situation of the VPP, and identifies and proposes the future research lines.

15 A Hybrid GA - Interval Linear Programming Implementation for Microgrid Relay Coordination Considering Different Fault Locations

ICPS 2017, Pune

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This paper proposes hybrid Genetic Algorithm (GA) - Interval Linear Programming (ILP) approach to optimal relay coordination problem for microgrids. Relay coordination in microgrids is complex because of varied and bidirectional fault currents because of the existence of Distributed Generation (DG). Overcurrent relays are the feasible and economic choice of protection for meshed distribution systems. The coordinated relay settings must account for various possible fault scenarios in both grid connected and isolated microgrid modes of operation. Inadequate fault current levels from grid connected to the isolated mode are the major cause of protection miscoordination. This paper systematically formulates the relay coordination problem for microgrids as a linear interval optimization problem and introduces a new method of solution using hybrid GA - ILP method. The challenge in using GA to find the optimum in less number of iterations and the feasibility of ILP method to include various fault scenarios as "uncertain but bounded" intervals are combined to find the optimal overcurrent relay settings. The results show the effectiveness of proposed method. The programming is done using optimization tool box available in Matlab

16 An Efficient Fault Detection Method in Grid Connected or Islanded Micro-Grid Using Network Power Flows

ICPS 2017, Pune

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Protection and Control of Micro-grids provide several great technical challenges for implementation of new techniques for reliable operation in grid-connected or islanded mode. This paper proposes an implementation procedure comprising of Cumulative sum (CUSUM) algorithm and bi-directional power flow method for fault detection in micro-grids. The Cumulative sum algorithm is found to be better suited than the traditional methods in the presence of noise, system frequency deviation, and other uncertainties for radial system. The fault detection in the micro-grid is carried out by monitoring the power-flowing between buses together with the principle of cumulative sum algorithm approach. The proposed algorithm is implemented and tested on a micro-grid system. Several transient disturbances viz. grid connection, single-phase to ground fault, 2-phase fault, 3- phase to ground faults, etc. occurring in different parts of the test micro-grid system are investigated. The algorithm was found to be robust and efficient.