

**Department: Electrical Engineering**

**3.4.5**

**Research papers per teacher in the Journals notified on UGC website**

**Supporting Documents**



3.4.5 Number of research papers per teacher in the Journals notified on UGC website during the last five years (15<sup>1</sup>)

3.4.5.1: Number of research papers in the Journals notified on UGC website during the last five years

| S. No | Title of paper                                                                                                                      | Name of the author/s                              | Department of the teacher                     | Name of journal                                                                                                 | Year of publication | ISSN number                                  | Link to the recognition in UGC enlistment of the Journal                                                                   | Scopus Indexed | Wb of science Indexed | No. of Citations in Scopus | No. of Citations in Web of science |
|-------|-------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------|-----------------------------------------------|-----------------------------------------------------------------------------------------------------------------|---------------------|----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|----------------|-----------------------|----------------------------|------------------------------------|
| 1     | Availability Assessment of Crop residue Potential for Electric Power Generation in Punjab, India: A review                          | H.S. Dhaliwal, Y.S. Brar and G.S. Brar            | Department of Electrical Engineering , IKGPTU | International Journal on Emerging Technologies; 11-1; 476-485                                                   | 2020                | 0975-8364                                    | Scopus preview - Scopus - International Journal on Emerging Technologies                                                   | YES            | YES                   |                            |                                    |
| 2     | Optimization for Biomass Based Plant Localization using NDVI Super Pixels for Punjab State, India                                   | H.S. Dhaliwal, Y.S. Brar and G.S. Brar            | Department of Electrical Engineering , IKGPTU | International Journal of Advanced Science and Technology; 29-6; 2723-2733                                       | 2020                | 2005-4238                                    | Scopus preview - Scopus - International Journal of Advanced Science and Technology                                         | YES            | YES                   | 3                          |                                    |
| 3     | Evaluation of Air Pollution due to Crop Residual Burning in Open Fields of Punjab, India                                            | H.S. Dhaliwal, Y.S. Brar and G.S. Brar            | Department of Electrical Engineering , IKGPTU | Journal of Advanced Research in Dynamical and Control Systems; 12-2; 2312-2321                                  | 2020                | 1943-023X                                    | Scopus preview - Scopus - Journal of Advanced Research in Dynamical and Control Systems                                    | YES            | YES                   |                            |                                    |
| 4     | Hybridized particle swarm optimization on constrained economic dispatch problem                                                     | N., Chopra, Y.S. Brar and J.S. Dhillon,           | Department of Electrical Engineering , IKGPTU | Journal of Computational and Theoretical Nanoscience; 17-1; 322-328;                                            | 2020                | 1546-1955                                    | Scopus preview - Scopus - Journal of Computational and Theoretical Nanoscience                                             | YES            | YES                   |                            |                                    |
| 5     | Software effort estimation using FAHP and weighted kernel LSSVM machine                                                             | S.K. Sehra, Y.S. Brar, N. Kaur and S.S. Sehra     | Department of Electrical Engineering , IKGPTU | Soft Computing; 23; 10881-10900                                                                                 | 2019                | 1433-7479                                    | Scopus preview - Scopus - Soft Computing                                                                                   | YES            | YES                   |                            |                                    |
| 6     | An integration of smart grids with demand side management and renewable energy: A review                                            | B. Koul, K., Singh and Y.S. Brar                  | Department of Electrical Engineering , IKGPTU | International Journal of Mechanical and Production Engineering Research and Development (IJMPERD); 9-4; 839-848 | 2019                | 2249-6890                                    | Scopus preview - Scopus - International Journal of Mechanical and Production Engineering Research and Development          | YES            | YES                   |                            |                                    |
| 7     | Solution of Optimal Power Flow Based on Active and Reactive Cost using Particle Swarm Optimization                                  | H.P. Singh, Y. S. Brar and D.P. Kothari           | Department of Electrical Engineering , IKGPTU | International Journal of Electrical Engineering & Technology (IJEET), vol. 10, no. 2, pp. 98-107,               | 2019                | ISSN Print: 0976-6545 and ISSN Online: 0976- | Scopus preview - Scopus - International Journal of Electrical Engineering and Technology                                   | YES            | YES                   |                            |                                    |
| 8     | Reactive power based fair calculation approach for multi-objective load dispatch problem                                            | H.P. Singh, Y.S. Brar and D.P. Kothari,           | Department of Electrical Engineering , IKGPTU | Archives of Electrical Engineering, vol. 68, no. 4, pp. 719-735,                                                | 2019                |                                              | Scopus preview - Scopus - Archives of Electrical Engineering                                                               | YES            | YES                   |                            |                                    |
| 9     | Fault detection in power transformers using random neural networks                                                                  | Amrinder Kaur, Y S Brar, Leena G                  | Department of Electrical Engineering , IKGPTU | International Journal of Electrical and Computer Engineering (IJECE) Vol. 9, No. 1, pp. 78-84                   | 2019                | 2088-8708                                    | https://www.scopus.com/sourceid/21100373959                                                                                | YES            | YES                   |                            |                                    |
| 10    | A Novel Based Algorithm for Fault Detection in Power Transformers                                                                   | Amrinder Kaur, Y S Brar, Leena G                  | Department of Electrical Engineering , IKGPTU | International Journal of Computer Engineering                                                                   | 2018                | 22501767                                     | https://www.researchgate.net/publication/322575223_A_Novel_ANFIS_based_Algorithm_for_Fault_Detection_in_Power_Transformers | YES            | YES                   |                            |                                    |
| 11    | Software effort estimation using FAHP and weighted kernel LSSVM machine                                                             | S.K. Sehra, Y.S. Brar, N. Kaur and S.S. Sehra     | Department of Electrical Engineering , IKGPTU | Soft computing, Soft Computing, vol. 23, pp. 10881-10900                                                        | 2018                | 1432-7643                                    | Scopus preview - Scopus - Soft Computing                                                                                   | YES            | YES                   |                            |                                    |
| 12    | Research Patterns & Trends in Software Effort Estimation                                                                            | Sehra SK, BrarYS, Kaur , Navdeep Kaur             | Department of Electrical Engineering , IKGPTU | Information & Software Technology                                                                               | 2017                | 0950-5849                                    | Scopus preview - Scopus - Information and Software Technology                                                              | YES            | YES                   |                            |                                    |
| 13    | Potential of Livestock Generated Biomass Untapped Energy Source in India                                                            | Gagandeep Kaur, Yadwinder Singh Brar, D.P Kothari | Department of Electrical Engineering , IKGPTU | Energies                                                                                                        | 2017                | 1996-1073                                    | Scopus preview - Scopus - Energies                                                                                         | YES            | YES                   |                            |                                    |
| 14    | Neural Based Algorithm for Fault Detection in a Transformer                                                                         | Amrinder Kaur, Y.S Brar , Leena G                 | Department of Electrical Engineering , IKGPTU | Fareast journal of electronics communication                                                                    | 2016                | 0973-7006                                    | Scopus preview - Scopus - Far East Journal of Electronics and Communications                                               | YES            | YES                   |                            |                                    |
| 15    | Application of Multi-criteria Decision Making in Software Engineering                                                               | Sehra S K, Brar YS, Kaur Navdeep                  | Department of Electrical Engineering , IKGPTU | International journal of advanced computer science & application                                                | 2016                | 2156-5570                                    | Scopus preview - Scopus - International Journal of Advanced Computer Science and Applications                              | YES            | YES                   |                            |                                    |
| 16    | Assessment of Capacitance for Self-Excited Induction Generator in Sustaining Constant Air gap Voltage under Variable Speed and Load | Ashish Sharma, Gagandeep Kaur                     | Department of Electrical Engineering , IKGPTU | Energies                                                                                                        | 2018                | 1996-1073                                    | Scopus preview - Scopus - Energies                                                                                         | YES            | YES                   |                            |                                    |
| 17    | Potential of Livestock Generated Biomass: Untapped Energy Source in India                                                           | Gagandeep Kaur, Yadwinder S.Brar, D.P.Kothari     | Department of Electrical Engineering , IKGPTU | Energies                                                                                                        | 2017                | 1996-1073                                    | Scopus preview - Scopus - Energies                                                                                         | YES            | YES                   |                            |                                    |

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|    |                                                                                                                                                            |                                                                                              |                                               |                                                                                     |      |           |                                                                                                       |     |     |   |    |
|----|------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|-----------------------------------------------|-------------------------------------------------------------------------------------|------|-----------|-------------------------------------------------------------------------------------------------------|-----|-----|---|----|
| 18 | Computation of Power Transformer Reactance using Finite Element Method                                                                                     | Vibhuti, Genius Wallia, Deepika Bhalla                                                       | Department of Electrical Engineering , IKGPTU | International Journal of Performance Engineering                                    | 2020 | 0973-1318 | <a href="https://www.scopus.com/sourceid/17500155116">https://www.scopus.com/sourceid/17500155116</a> | YES | YES |   |    |
| 19 | Analyzing Short Circuit Forces in Transformer for Double Layer Helical LV Winding using FEM                                                                | Deepika Bhalla, Raj Kumar Bansal, Hari Om Gupta                                              | Department of Electrical Engineering , IKGPTU | International Journal of Performability Engineering                                 | 2018 | 0973-1318 | <a href="https://www.scopus.com/sourceid/17500155116">https://www.scopus.com/sourceid/17500155116</a> | YES | YES |   |    |
| 20 | Photo-Voltaic based Smart Irrigation Cart                                                                                                                  | Amit Anand, Anuj Banshwar, Naveen Kumar Sharma, Bharat Bhushan Sharma and Mohit Pathak       | Department of Electrical Engineering , IKGPTU | Journal of Physics: Conference Series                                               | 2020 | 1742-6588 | Scopus preview - Scopus - Journal of Physics: Conference Series                                       | YES | YES |   |    |
| 21 | Power Quality Assessment of Distorted Distribution Networks Incorporating Renewable Distributed Generation Systems Based on the Analytic Hierarchy Process | M. Bajaj, A. K. Singh, M. Alowaidi, N. K. Sharma, S. K. Sharma and S. Mishra                 | Department of Electrical Engineering , IKGPTU | IEEE Access                                                                         | 2020 | 2169-3536 | Scopus preview - Scopus - IEEE Access                                                                 | YES | YES |   | 7  |
| 22 | Market-based Participation of Energy Storage Scheme to Support Renewable Energy Sources for the Procurement of Energy and Spinning Reserve                 | Anuj Banshwar, Naveen Kumar Sharma, Yog Raj Sood, Rajnish Shrivastava                        | Department of Electrical Engineering , IKGPTU | Renewable Energy                                                                    | 2019 | 0960-1481 | Scopus preview - Scopus - Renewable Energy                                                            | YES | YES |   | 9  |
| 23 | Simulation based Elevator Group Control System for Multi Storey Building                                                                                   | Bharat Bhushan Sharma, Anuj Banshwar, Mohit Pathak, Naveen Kumar Sharma, Aman Joshi          | Department of Electrical Engineering , IKGPTU | International Journal of Mathematical, Engineering and Management Sciences (IJMEMS) | 2019 | 2455-7749 | Scopus preview - Scopus - International Journal of Mathematical, Engineering and Management Sciences  | YES | YES |   |    |
| 24 | "Mixed GA-OPF based Optimal Procurement of Energy and Operating Reserve in Deregulated Environment                                                         | Anuj Banshwar, Naveen Kumar Sharma, Bharat Bhushan Sharma, Yog Raj Sood, Rajnish Shrivastava | Department of Electrical Engineering , IKGPTU | Journal of Intelligent & Fuzzy Systems                                              | 2018 | 1064-1246 | Scopus preview - Scopus - Journal of Intelligent and Fuzzy Systems                                    | YES | YES |   | 1  |
| 25 | Mixed GA-OPF based Prioritized Optimal Location and Rating of Wind Power Generation in Deregulated Electricity Market                                      | Naveen Kumar Sharma, Anuj Banshwar, Bharat Bhushan Sharma, Yog Raj Sood, Rajnish Shrivastava | Department of Electrical Engineering , IKGPTU | Journal of Intelligent & Fuzzy Systems                                              | 2018 | 1064-1247 | Scopus preview - Scopus - Journal of Intelligent and Fuzzy Systems                                    | YES | YES | 2 | 2  |
| 26 | Simultaneous Optimization of Renewable Energy Based Pumped Storage Scheme in Energy and Ancillary Services Market under Deregulated Power sector           | Souvik Roy, Anuj Banshwar, Naveen Kumar Sharma, Yog Raj Sood                                 | Department of Electrical Engineering , IKGPTU | Journal of Intelligent & Fuzzy Systems                                              | 2018 | 1064-1248 | Scopus preview - Scopus - Journal of Intelligent and Fuzzy Systems                                    | YES | YES |   | 2  |
| 27 | An International Experience of Technical and Economic Aspects of Ancillary Services in Deregulated Power Industry: Lessons for Emerging BRIC Markets       | Anuj Banshwar, Naveen Kumar Sharma, Yog Raj Sood, Rajnish Shrivastava                        | Department of Electrical Engineering , IKGPTU | Renewable and Sustainable Energy Reviews                                            | 2018 | 1364-0321 | Scopus preview - Scopus - Renewable and Sustainable Energy Reviews                                    | YES | YES |   | 14 |
| 28 | Real time procurement of energy and operating reserve from Renewable Energy Sources in deregulated environment considering imbalance penalties             | Anuj Banshwar, Naveen Kumar Sharma, Yog Raj Sood, Rajnish Shrivastava                        | Department of Electrical Engineering , IKGPTU | Renewable Energy                                                                    | 2017 | 0960-1481 | Scopus preview - Scopus - Renewable Energy                                                            | YES | YES |   | 13 |
| 29 | Renewable Energy Sources as a New Participant in Ancillary Service Markets                                                                                 | Anuj Banshwar, Naveen Kumar Sharma, Yog Raj Sood, Rajnish Shrivastava                        | Department of Electrical Engineering , IKGPTU | Energy Strategy Reviews,                                                            | 2017 | 2211-467X | Scopus preview - Scopus - Energy Strategy Reviews                                                     | YES | YES |   | 43 |
| 30 | Optimal location and rating of wind power plants in competitive electricity market                                                                         | Anuj Banshwar, Naveen Kumar Sharma, Yog Raj Sood, Rajnish Shrivastava                        | Department of Electrical Engineering , IKGPTU | Journal of Renewable and Sustainable Energy                                         | 2017 | 1941-7012 | Scopus preview - Scopus - Journal of Renewable and Sustainable Energy                                 | YES | YES |   | 10 |
| 31 | Market Based Procurement of Energy and Ancillary Services from Renewable Energy Sources in Deregulated Environment                                         | Anuj Banshwar, Naveen Kumar Sharma, Yog Raj Sood, Rajnish Shrivastava                        | Department of Electrical Engineering , IKGPTU | Renewable Energy                                                                    | 2017 | 0960-1481 | Scopus preview - Scopus - Renewable Energy                                                            | YES | YES |   | 30 |
| 32 | Power quality analysis of an AC utility-grid interfaced multilevel inverter systems                                                                        | Akhil Gupta                                                                                  | Department of Electrical Engineering , IKGPTU | International Journal of Electronics Letters                                        | 2020 | 2168-1732 | Scopus preview - Scopus - International Journal of Electronics Letters                                | YES | YES |   |    |
| 33 | Islanding Detection Using Passive Technique                                                                                                                | Singh N. and Akhil Gupta                                                                     | Department of Electrical Engineering , IKGPTU | International Journal of Pure and Applied Mathematics                               | 2018 | 1314-3395 | Scopus preview - Scopus - International Journal of Pure and Applied Mathematics                       | YES | YES |   |    |
| 34 | Influence of solar photovoltaic array on operation of grid-interactive fifteen-level modular multilevel converter with emphasis on power quality           | Akhil Gupta                                                                                  | Department of Electrical Engineering , IKGPTU | Renewable & sustainable energy reviews                                              | 2017 | 1364-0321 | Scopus preview - Scopus - Renewable and Sustainable Energy Reviews                                    | YES | YES |   |    |
| 35 | A hybrid model of a grid connected solar photovoltaic (PV) cell with partial shading                                                                       | Akhil Gupta                                                                                  | Department of Electrical Engineering , CU     | Indian Journal of Science and Technology                                            | 2016 | 0974-5645 | Scopus preview - Scopus - Indian Journal of Science and Technology                                    | YES | YES |   |    |
| 36 | Comparative power quality analysis of different discontinuous phase control grid-interactive converter systems                                             | Akhil Gupta                                                                                  | Department of Electrical Engineering , CU     | International Journal of Control Theory and Applications                            | 2016 | 0974-5572 | Scopus preview - Scopus - International Journal of Control Theory and Applications                    | YES | YES |   |    |

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## Availability Assessment of Crop residue Potential for Electric Power Generation in Punjab, India: A Review

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(Received 16 November 2019, Revised 03 January 2020, Accepted 09 January 2020)

(Published by Research Trend, Website: [www.researchtrend.net](http://www.researchtrend.net))

**ABSTRACT:** Biomass residues are renewable, reliable and economical resource of energy for both developed and developing countries. Punjab being an agricultural dominating state has innumerable prospective of agricultural crop residues. This paper reviews the results obtained from various previous studies, which had estimated the crop residue potentials for power generation in the state. If we use this crop residue as a fuel in biomass power plants, it will not only provide enough electric power to the state but also provide solution to the biggest setback of burning the crop residues in the fields of state. The viability and practicability of exhilarate the new biomass power plants primarily depends upon the availability of fuel i.e. crop residue. Hence before planning to find the optimal locations of biomass power plants and centers for collecting the fuel in the state, it is quiet necessary to evaluate the availability of agricultural crop residues biomass and energy content of this biomass for electric power generation. In the end study summarizes that there is enough crop residue potential in the state for electric power generation.

**Keywords:** Punjab, crop residue, power generation, resources, agricultural biomass.

### I. INTRODUCTION

Electrical energy plays an important role in our life. Electricity is necessary for improving the living standards and also a crucial input for socio-economic activities of any nation. Substandard electricity supply severely obstructs the health, education and agricultural activities in rural as well as urban areas [1]. The electricity demand in Punjab state is envisage rising significantly owing to increasing population, Sharp rise in agricultural and industrial applications and upliftment of the living standards of people [2]. It is a matter of dread that the available conventional sources in the country might not be able to fulfill the energy needs of the nation as well as the Punjab state [3]. The state is not rich in natural resources of fossil fuels, nor have the abundant sources of hydro electric power. The state has to rely far away states for supply of coal and to depend upon the neighboring states for hydro electric power [4]. As per the reports of World Energy Forum, the conventional energy sources of the country will deplete soon in the coming few decades [5]. Also the green house gases produced from the burning of coal and petroleum highly pollutes the air. These green house gases are the important factor for global climate change [6]. The diminution of fossil fuels and serious environmental issues raised from burning of fossil fuels leads the governments to switch the electric power generation to the alternate energy sources such as biomass [7]. Agricultural biomass residue is one of the

most widely used fuels for electric power generation all around the world nowadays. The use of biomass as a fuel can decrease the green house gases emissions [8]. The carbon dioxide emitting from burning of crop residue is balanced by amount absorbed when the plants are grown, as a process of photosynthesis. Hence we can say that crop residues are of immense interest to the farmers of the state. The farmers burn a large amount of crop residues in their fields to prepare the fields for sowing of the next crop. Burning of crop residues particularly paddy residue is the most critical and serious issue for the farmers of north India. Punjab, Haryana, Rajasthan and Uttar Pradesh are the most affected states from north India. The problem of burning crop residue is most severe in mechanized rice-wheat system in the Punjab state [9]. Some of the main reasons of burning paddy residue are the short time frame between sowing of wheat crop and harvesting of rice crop, inadequacy of labour and economical issues related to labour, use of combine harvesters and lack of storage and collection centers and insufficient purchase of crop residues in the market.

The objective of this study is to review the availability of agricultural residue produced in agricultural sector of Punjab and the potential of this crop residue to generate electrical energy in the state of Punjab, which is one of the wealthiest states in terms of agriculture in the country.



## OPTIMIZATION FOR BIOMASS BASED PLANT LOCALIZATION USING NDVI SUPER PIXELS FOR PUNJAB STATE, INDIA

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### Abstract

Punjab state holds third position in crop production in INDIA [1]. As crop production is directly proportional to the amount of crop residual produced, handling of this large crop residual in an efficient manner is a challenge. A big amount of crop residual gets used in the form of fodder, thatching, manuring and fuel wood, but a common practice to burn the remaining crop residual in open fields will led to serious health hazards[2]. Study shows total unused crop residual for year 2017-18 is 14736.1 kty<sup>-1</sup>, which have the potential to generate around 1938.94 MWy<sup>-1</sup>. Proposed work optimizes the bio-based power plant locations along with its collection centers to use crop residual. Mathematical models have been developed to locate geo centers to reduce transportation cost. Study shows each bio-based power plant has the tendency to produce minimum of 124.52 MWy<sup>-1</sup>. Landsat8 bands followed by NDVI and super pixel calculations used to enhance optimal model performance.

**Keywords:** biomass power plants, biomass collection centers, Bat optimization, super pixels, power potential, Net surplus, crop residual, NDVI.

**Abbreviations:** AQI, Air Quality Index; NDVI, Normalized Difference Vegetation Index; USGS, United States Geological Survey; GIS, Geographical Information System; RGB, Red Green Blue; CRR, Crop Residual Ratio; NIR, Near Infrared

### 1. Introduction

Pollution is always been a problem for the humans by the humans. Over the years this problem has evolved drastically. India is considered as one of the most polluted countries. The AQI of most of the cities in India lies in the range of unhealthy category. There are many reasons behind this and one of them is burning of crops [3]. India is in the top three countries when it comes to wheat and rice production around the world. This proportionally states that a lot of crop residual is left. Currently this residual is simply burned which degrades the air quality. But if we build biomass treatment plant which will help to generate power from this residual then it will not only reduce the air pollution but also provide power in an eco-friendly manner [4]. In this study we will be optimizing the location of these biomass power plants and collection centers in one of the highest crops producing state of India that is Punjab. Punjab covers 1.5% of the total geographical area of India but it roughly produces one third of the whole crops production of the country [5].

The study also shows that huge amount of surplus agricultural residue is available in Punjab state, which may be utilized for electric power generation in decentralized power plants [6]. This clearly states that it has high crop residual quantity to deal with. This study will optimize the location for the biomass power plants along with collection centers as well. These collection centers will be the points or storage houses where biomass can be collected and stored from the nearby area. Further, this biomass will then be transferred to the main facility that is biomass power plant. Locations of these biomass plants will be optimized by our algorithm. These plants will convert biomass into consumable energy which will directly benefit the state itself. Optimization of biomass facility location is nothing new, many researchers have done this earlier but there is still need a lot of improvement. Our approach is to provide the most convenient and efficient locations for these facilities by keeping various parameters in account.

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# ARCHIVES

## Evaluation of Air Pollutants due to Crop Residual Burning in Open Fields of Punjab, India

Harpreet Singh Dhaliwal, Yadwinder Singh Brar, Gursewak Singh Brar,

### Abstract

Air pollution has been increasing gradually since the last two decades. There are many harmful effects of air pollution, which directly or indirectly affect humans. Emission of harmful pollutants in the atmosphere causes air pollution. These pollutants are released from various sources; one of them is crop residual burning. Punjab (India) is one of the most crop producing states in the country. Burning of crop residual in this state emits a large amount of harmful pollutants such as CO<sub>2</sub>, CO, NO<sub>2</sub>, and PM<sub>2.5</sub> etc. On the other hand, if crop residual is used for biomass power generation then it will not only decelerate the increase of pollutants but will also provide electrical energy. Proposed study predicts the emitting pollutant's quantity by using landsat8 bands of USGS during crop residual burning and its equivalent power potential if used as a fuel for biomass power plants. Based on the results, it has been observed that a significant quantity of pollutants can be reduced by practicing biomass power generation. This study also highlights various other advantages such as coal saving and financial benefit to the farmers. Practicing biomass power generation can reduce the stress on fossil fuels like coal for power generation; this practice can also provide financial support to the farmers.

Volume 12 | Issue 2

Pages: 2312-2321

DOI: 10.5373/JARDCS/V12I2/S20201277 ()

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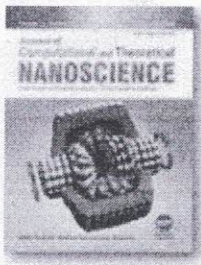
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# Hybridized Particle Swarm Optimization on Constrained Economic Dispatch Problem

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**Source:** Journal of Computational and Theoretical Nanoscience, Volume 17, Number 1, January 2020, pp. 322-328(7)

**Publisher:** American Scientific Publishers

**DOI:** <https://doi.org/10.1166/jctn.2020.8669>



Abstract



References



Citations



Supplementary Data



Suggestions

The hybridization of particle swarm optimization (PSO) with simplex search method (SSM) is presented on the problem of economic dispatch in the thermal plants so as to minimize the overall operating fuel cost while subjected to various constraints. This hybridization of stochastic with deterministic optimization method helps the global optimum solution to further refine by the local search. It also overcomes some of the drawbacks of conventional PSO like premature convergence and stagnation in the solution if the number of iterations are increased. This proposed optimization method is used to get the overall minimum cost of fuel by including transmission line losses and valve point loading effect (VPLE) in the classical problem of economic dispatch, so as to have the more practical impact in the case considered. The validity of the suggested algorithm is tested using small scale and large scale system and the analogy of results obtained are done with existing algorithms cited in the literature, showing improvement of 29.3% in small scale system and 6.4% in large scale system, which proves the robustness of the suggested approach.

**Keywords:** Economic Dispatch; Particle Swarm Optimization; Simplex Search Method; Valve Point Loading Effect

**Document Type:** Research Article

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Publication date: January 1, 2020

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**We recommend**





# Software effort estimation using FAHP and weighted kernel LSSVM machine

Sumeet Kaur Sehra<sup>1,2</sup> · Yadwinder Singh Brar<sup>1</sup> · Navdeep Kaur<sup>3</sup> · Sukhjot Singh Sehra<sup>4</sup>

Published online: 4 December 2018  
© Springer-Verlag GmbH Germany, part of Springer Nature 2018

## Abstract

In the life cycle of software product development, the software effort estimation (SEE) has always been a critical activity. The researchers have proposed numerous estimation methods since the inception of software engineering as a research area. The diversity of estimation approaches is very high and increasing, but it has been interpreted that no single technique performs consistently for each project and environment. Multi-criteria decision-making (MCDM) approach generates more credible estimates, which is subjected to expert's experience. In this paper, a hybrid model has been developed to combine MCDM (for handling uncertainty) and machine learning algorithm (for handling imprecision) approach to predict the effort more accurately. Fuzzy analytic hierarchy process (FAHP) has been used effectively for feature ranking. Ranks generated from FAHP have been integrated into weighted kernel least square support vector machine for effort estimation. The model developed has been empirically validated on data repositories available for SEE. The combination of weights generated by FAHP and the radial basis function (RBF) kernel has resulted in more accurate effort estimates in comparison with bee colony optimisation and basic RBF kernel-based model.

**Keywords** Software effort estimation · Fuzzy analytic hierarchy process · Least square support vector machine

## 1 Introduction

Software engineering (SE) discipline has evolved since the 1960s and has garnered significant knowledge (Zelkowitz et al. 1984). Academia and industry have invested in SE research and development in past decades that resulted in the development of improved tools, methodologies and techniques. Over the years, there has been an intense criticism of SE research as it advocates more than it evaluates (Glass et al. 2002). Many researchers have attempted to characterise SE research, but they failed to present a comprehensive picture (Jørgensen et al. 2009; Shaw 2002).

Software effort estimation (SEE) is a critical component that predicts the effort to accomplish development or maintenance tasks based on historical data. Accurate estimates are critical to company and customers because it can help the company personnel to classify, prioritise and determine resources to be committed to the project (Nisar et al. 2008). Since its inception, the problems and issues in SEE have been addressed by researchers and practitioners. The researchers have proposed numerous estimation methods since the inception of SE as a research area (Jørgensen and Shepperd 2007; Rastogi et al. 2014; Trendowicz et al. 2008). The application of developed models has been found to be appropriate for the specific types of the development environment. The advances in the technology stack and frequent changing user requirements have made the process of SEE difficult. Numerous approaches have been tried to predict this probabilistic process accurately, but no single technique has performed consistently. Even, few researchers have tried to employ a combination of the approaches rather than a single approach. The major reason for inaccurate estimates is that datasets of past projects are usually sparse, incomplete, inconsistent and not well documented. Another reason for this is that SEE process is dependent on multiple/seen and unseen factors.

Communicated by V. Loia.

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## AN INTEGRATION OF SMART GRIDS WITH DEMAND SIDE MANAGEMENT AND RENEWABLE ENERGY: A REVIEW

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### ABSTRACT

*The scheduling and improvement of the intelligible smart grid (SG) system is a combined part of the revolutionary target of accomplishing the distributed energy generation and transmission. The progression based on the fossil generation to the smart and renewable systems involves incorporation of innovative procedures at the utility as well as consumer end. It is evident from the present scenario that requirement of customer's demand-side methods expanding at present, and also more prospects in this area are to be accomplished. This paper presents the integration of demand side management (DSM), demand response (DR) and renewable energy in SG systems. The existing literature on DR and DSM integration has been discussed by studying current and relevant publications of journals and conferences in this research area.*

**KEYWORDS:** Smart Grid, Demand Response Demand Side Management & Renewable Energy

Received: May 18, 2018; Accepted: Jun 08, 2019; Published: Jul 11, 2019; Paper Id.: IJMPERDAUG201986

### INTRODUCTION

SG transfers the bidirectional power between the electricity suppliers and customers with the help of computational proficiency to save energy, operation cost and be an ecologically favourable system. The significant factors responsible for a transaction from conventional system to today's bidirectional power market are larger electricity demand, use of several renewable energy sources, greater peak load demand and an old network arrangement. The SG is also responsible for increasing the communication and synchronization among different parties associated with this bidirectional communication accomplished for stretched transmission networks or confined distribution systems. Among the substantial features of SG major one is to sanction bidirectional communication between the performers in the grid so as to optimize electricity usage, and involvement of users to enhance the efficiency of conventional power system. DR states to consumption of power from the regular consumption patterns in response to deviations in the price of electricity for a specific duration. DR can also be defined as the monetary motivations that are planned to convince lesser consumption of power when wholesale market prices are at peak or when system consistency is threatened [1,2].

The further organization of the paper includes section II which presents the impact of DR on monetary and power situations of SG, section III explains the literature review on influence of DR and SG, while section IV contains a combination of DR in SG environment and finally section V concludes with several characteristics discussed in the paper.



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SCOPUS Indexed Journal Kapurthala-144006



# SOLUTION OF OPTIMAL POWER FLOW BASED ON COMBINED ACTIVE AND REACTIVE COST USING PARTICLE SWARM OPTIMIZATION

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**ABSTRACT**

*Thermal power generators have both active power (AP) and reactive power (RP) requirement to meet up the total power demand. Considering the total power demand such generators supply the essential RP along with the AP. Consequently by considering the reactive power demand it is also an important to consider its cost along with the cost based on active power generation. In this paper, the generalised mathematical functions for the cost considering the RP are formulated and incorporated with the cost function based on active power generation. Particle Swarm Optimization (PSO) algorithm has been applied to solve Optimal power flow (OPF) problem (OPFP). The proposed work has been examined and tested on IEEE-9 bus system with different objectives such as total fuel cost based both active and reactive power generation, transmission losses, voltage profile improvement. The results drawn show its validity and effectiveness*

**Keywords:** Economic Load dispatch, Reactive power pricing, Optimal Power Flow, Particle Swarm Optimization.

**Cite this Article:** Harinder Pal Singh, Yadwinder Singh Brar and D. P. Kothari, Solution of Optimal Power Flow Based on Combined Active and Reactive Cost using Particle Swarm Optimization, *International Journal of Electrical Engineering and Technology*, 10(2), 2019, pp. 98-107.

<http://www.iaeme.com/IJEET/issues.asp?JType=IJEET&VType=10&IType=2>

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# Reactive power based fair calculation approach for multiobjective load dispatch problem

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(Received: 21.01.2019, revised: 30.04.2019)

**Abstract:** This paper proposes a fair calculation approach for the cost and emission of generators. Generators also have reactive power requirements along with the active power demand to meet up the total power demand. In this paper, firstly the reactive power is calculated considering the random active power operating points on the capability curve of a generator then the cost for reactive power generation as well as emission are calculated. In order to develop the mathematical function for the reactive power cost and reactive power emission, a curve-fitting technique is applied, which gives the generalized reactive power cost and reactive power emission functions. At the end, the problem is formulated as a multiobjective problem, considering conflicting objectives such as combined active-reactive economic dispatch and combined active-reactive emission dispatch. The problem is converted from the multiobjective load dispatch problem (MOLDP) into a scalar problem, using the weighting method and the best compromised solution has been calculated using the particle swarm optimization (PSO) technique. A fuzzy cardinal method has been applied to choose the best solution. In order to demonstrate the efficiency of developed functions the proposed method is applied on a 3 generator unit system and a 10 generator unit system, the results obtained show its validity and effectiveness.

**Key words:** combined active reactive economic dispatch, combined active reactive emission dispatch, economic load dispatch, multiobjective load dispatch

## 1. Introduction

Under the economic load dispatch (ELD) problem (ELDP) the foremost objective is to minimize the operating cost by scheduling the committed generating unit outputs so as to meet the load demand. The ELDP is defined as the method of decreasing the total generation fuel cost



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## Fault detection in power transformers using random neural networks

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### Article Info

#### Article history:

Received Apr 4, 2018

Revised Jul 5, 2018

Accepted Aug 2, 2018

#### Keywords:

Dissolved gas analysis (DGA)

Fault diagnosis

Power transformer

Random neural network (RNN)

### ABSTRACT

This paper discuss the application of artificial neural network-based algorithms to identify different types of faults in a power transformer, particularly using DGA (Dissolved Gas Analysis) test. The analysis of Random Neural Network (RNN) using Levenberg-Marquardt (LM) and Broyden-Fletcher-Goldfarb-Shanno (BFGS) algorithms has been done using the data of dissolved gases of power transformers collected from Punjab State Transmission Corporation Ltd.(PSTCL), Ludhiana, India. Sorting of the preprocessed data have been done using dimensionality reduction technique, i.e., principal component analysis. The sorted data is used as inputs to the Random Neural Networks (RNN) classifier. It has been seen from the results obtained that BFGS has better performance for the diagnosis of fault in transformer as compared to LM.

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## 1. INTRODUCTION

Power transformer is one of the important equipment in power system. The fault in transformer causes breakdown in power system which produces financial losses to power industry and inconvenience to the end user. In power transformers, liquid insulation in the form of mineral oil/transformer oil is being used as cooling agent. An impregnated insulation cellulose/paper is also used as solid insulation in transformer. Transformer oil as liquid insulation is very important as it provides electrical insulation, dissipates heat as cooling agent, protect the core & winding and does isolation and moreover, prevent direct contact of atmospheric oxygen with winding.

Paper insulation of winding deteriorate with time of usage which results in deterioration of solid insulation [1], [2], [3]. The liquid insulation (transformer oil) when heated up due to working of transformer, decomposes and produce gases like hydrogen (H<sub>2</sub>), methane (CH<sub>4</sub>), acetylene (C<sub>2</sub>H<sub>2</sub>), ethylene (C<sub>2</sub>H<sub>4</sub>) and ethane (C<sub>2</sub>H<sub>6</sub>). These gases deteriorate the quality of transformer oil and further its properties as coolant and insulator are affected which may result in breakdown of transformer as equipment in power supply. This can be prevented by knowing the amount of gases dissolved in the transformer oil at regular intervals of time of usage. The conventional methods like Roger's ratio method, Dornenburg's method, Duval's triangle method and key gas ratio methods are used to find the fault in respect of amount of harmful gases dissolved in the transformer oil. But, these methods sometimes give a false fault type [4], [5]. To improve these anomalies in conventional methods, various software based intelligent methods such as artificial neural networks [6], [7], [8], [9], [11], Wavelet Analysis, Least Vector Quotient, Probabilistic Neural Network (PNN), fuzzy logic, Support Vector Machine classifiers and Self-Organizing Map classifiers have been

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# A Novel ANFIS based Algorithm for Fault Detection in Power Transformers

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## ABSTRACT

Power Transformers are important parts of the power distribution network, used to change voltages level for transmission between sub stations and electricity consumers. Power Transformers are prone to failure due to general ageing of parts, which can lead to high replacement costs. It not only interrupts the supply of electricity, but can cause explosion and potentially halting the power network. Dissolved Gas Analysis (DGA) is a reliable technique for detecting the presence of incipient fault conditions in oil immersed transformers in which the presence of certain key gases is monitored. In this paper a novel algorithm based on ANFIS (Adaptive Neural And Fuzzy Inference System) using different fuzzy membership function is proposed and it is validated on DGA data obtained from PSTCL (Punjab State Transmission Corporation Ltd.) located at Patiala & Ludhiana. The key gases considered are hydrogen, methane, ethane, ethylene, acetylene..

## General Terms

Fuzzy Logic, ANFIS

## Keywords

Power Transformer, DGA, ANFIS, Fault Diagnosis.

## 1. INTRODUCTION

Mineral oils contain many different hydrocarbon molecules. They consist of essentially of saturated hydrocarbon called paraffin whose general molecular formula is  $C_n H_{2n+2}$  with  $n$  in the range of 2 to 40. The mineral oil acts as a dielectric medium as well as a heat transfer agent. The decomposition of electrical insulating materials and related components inside the transformer generates gases within the transformer. The amount of these gases can be related to the type of electrical fault, and the rate of gas generation can indicate the severity of the fault. The type of the gases being generated by a particular unit can provide useful information in any preventive maintenance program. There are several techniques in detecting fault gases and DGA is recognized as the most informative method. This method is based on sampling of the oil to measure the concentration of the dissolved gases. There are several methods developed to do the interpretation of the fault type from the dissolved gases data. The gas ratios are evaluated by using different method such as Dornenberg method [4], Roger's Ratio Method [3], Key Gases Method [5, 6], and Duval Triangle Method [7] as well as the recently developed techniques such as neural network and fuzzy logic. All the above techniques depend upon the ratios of gases evolved during the testing of the power transformer. The conventional DGA schemes have the following limitations:

1. Gas ratios or methods defined by these schemes are mainly developed based on human judgment. No systematic attempt has been made to actually 'learn' from the measured DGA data.
2. There is still a high degree of inconsistency and ambiguity when applying these schemes, owing to incompleteness of the possible ratio combinations and doubts on the validity of the defined ratio ranges.
3. These schemes are still unable to detect with high confidence multiple faults, which occur concurrently within the transformer.
4. These schemes are unable to detect new or unknown faults owing to the lack of expert knowledge in them.
5. In order to apply these methods, first calculation of gas ratios and then code depending upon ratio are used to find the fault instead of direct reading of gas concentration. Though key gas ratio method [5, 6] is used to find fault in the transformer but it is not able to identify all the faults as obtained by other methods.

The application of Artificial Intelligence (AI) techniques has largely improved transformer condition monitoring and assessment in recent years [13]-[17]. Decision-making context for power transformer fault detection problems involves vague, imprecise or incomplete knowledge and information. The Artificial Intelligence techniques are replacing the human interface for Power Transformer Fault detection, giving rise to concepts of automated diagnosis. Many practical transformer operation problems can now be solved by AI-based condition monitoring and assessment systems. In this paper, a novel algorithm based upon ANFIS using different fuzzy membership function is proposed for predicting the fault based upon gas concentration. The paper is organized as follows Section-2 gave a brief description about ANFIS and its structure. Section-3 defines the problem statement. Section-4 gave the results and discussions and Section-5 explains conclusion.

## 2. ANFIS

The conditions of a transformer being monitored can linguistically; for example, equipment condition is not necessarily 'good' or 'bad', but rather exists within an intermediate range. Notably, Fuzzy Logic is suitable in such circumstances, where condition monitoring input signals can be associated with membership functions. A membership function allows quantities to be associated with a linguistic variable with a degree of confidence. The fuzzy logic is a

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# Software effort estimation using FAHP and weighted kernel LSSVM machine

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## Abstract

In the life cycle of software product development, the software effort estimation (SEE) has always been a critical activity. The researchers have proposed numerous estimation methods since the inception of software engineering as a research area. The diversity of estimation approaches is very high and increasing, but it has been interpreted that no single technique performs consistently for each project and environment. Multi-criteria decision-making (MCDM) approach generates more credible estimates, which is subjected to expert's experience. In this paper, a hybrid model has been developed to combine MCDM (for handling uncertainty) and machine learning algorithm (for handling imprecision) approach to predict the effort more accurately. Fuzzy analytic hierarchy process (FAHP) has been used effectively for feature ranking. Ranks generated from FAHP have been integrated into weighted kernel least square support vector machine for effort estimation. The model developed has been empirically validated on data repositories available for SEE. The combination of weights generated by FAHP and the radial basis function (RBF) kernel has resulted in more accurate effort estimates in comparison with bee colony optimisation and basic RBF kernel-based model.

**Keywords** Software effort estimation · Fuzzy analytic hierarchy process · Least square support vector machine

## 1 Introduction

Software engineering (SE) discipline has evolved since the 1960s and has garnered significant knowledge (Zelkowitz et al. 1984). Academia and industry have invested in SE research and development in past decades that resulted in the development of improved tools, methodologies and techniques. Over the years, there has been an intense criticism of SE research as it advocates more than it evaluates (Glass et al. 2002). Many researchers have attempted to characterise SE research, but they failed to present a comprehensive picture (Jørgensen et al. 2009; Shaw 2002).

Software effort estimation (SEE) is a critical component that predicts the effort to accomplish development or maintenance tasks based on historical data. Accurate estimates are critical to company and customers because it can help the company personnel to classify, prioritise and determine resources to be committed to the project (Nisar et al. 2008). Since its inception, the problems and issues in SEE have been addressed by researchers and practitioners. The researchers have proposed numerous estimation methods since the inception of SE as a research area (Jørgensen and Shepperd 2007; Rastogi et al. 2014; Trendowicz et al. 2008). The application of developed models has been found to be appropriate for the specific types of the development environment. The advances in the technology stack and frequent changing user requirements have made the process of SEE difficult. Numerous approaches have been tried to predict this probabilistic process accurately, but no single technique has performed consistently. Even, few researchers have tried to employ a combination of the approaches rather than a single approach. The major reason for inaccurate estimates is that datasets of past projects are usually sparse, incomplete, inconsistent and not well documented. Another reason for this is that SEE process is dependent on multiple seen and unseen factors.


Communicated by V. Lora.

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Published online: 04 December 2018

  
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Contents lists available at ScienceDirect

# Information and Software Technology

journal homepage: [www.elsevier.com/locate/infsof](http://www.elsevier.com/locate/infsof)



## Research patterns and trends in software effort estimation

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### ARTICLE INFO

**Article history:**

Received 14 August 2016

Revised 23 March 2017

Accepted 7 June 2017

Available online 10 June 2017

**Keywords:**

Software effort estimation

Latent Dirichlet allocation

Research trends

### ABSTRACT

**Context:** Software effort estimation (SEE) is most crucial activity in the field of software engineering. Vast research has been conducted in SEE resulting into a tremendous increase in literature. Thus it is of utmost importance to identify the core research areas and trends in SEE which may lead the researchers to understand and discern the research patterns in large literature dataset.

**Objective:** To identify unobserved research patterns through natural language processing from a large set of research articles on SEE published during the period 1996 to 2016.

**Method:** A generative statistical method, called Latent Dirichlet Allocation (LDA), applied on a literature dataset of 1178 articles published on SEE.

**Results:** As many as twelve core research areas and sixty research trends have been revealed; and the identified research trends have been semantically mapped to associate core research areas.

**Conclusions:** This study summarises the research trends in SEE based upon a corpus of 1178 articles. The patterns and trends identified through this research can help in finding the potential research areas.

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### 1. Introduction

Software Engineering (SE) discipline has evolved since 1960s and has garnered significant knowledge [1]. Over the years, there has been a strong criticism of SE research as it advocates more than it evaluates [2]. Many researchers have attempted to characterize software engineering research, but they failed to present a comprehensive picture [3,4]. SEE predicts the effort to accomplish development or maintenance tasks based on data which is generally incomplete, uncertain and noisy. Problems and issues in SEE have been addressed by researchers and practitioners from time to time. But much of the research has its focus on construction of formal SEE models [5]. The models designed by researchers have known advantages and disadvantages. The vast available literature on the subject posed a challenge before the researchers to review and identify the right path for their research.

The literature can be reviewed manually or algorithmically. The manual review provides an insight into the literature, but it is never free from biasness as researchers remain inclined towards more cited papers [6]. Natural language processing provides a powerful algorithm that extracts unobserved trends from a large collection of documents. Unlike manual tagging, which is effort in-

tensive and requires expertise in the documents' subject-matter, algorithmic-based analysis is an automated process [7–9] called topic modelling. It takes a corpus, identifies the patterns and adds semantic meaning to the vocabulary. Both clustering and topic analysis approaches can be used with topic modelling. But as suggested by Evangelopoulos et al. [10], topic analysis is more appropriate relative to clustering for identification of research trends underlying the dataset. In topic analysis, a document is assigned to a mixture of topics, whereas in the case of clustering, each document is forced to join exactly one cluster. In this review, topic analysis and labelling have been incorporated to identify the latent patterns and trends in dataset. Two leading topic modelling techniques are Latent Semantic Indexing (LSI) [11] and Latent Dirichlet Allocation (LDA) [12]. In SE, LDA has been applied for mining software repositories [13], bug localization [14], defect prediction [15], software categorisation [16], classification of change messages [17] and software evolution [18].

Research patterns in SEE have been systematically identified and represented in this study by applying LDA to a corpus of 1178 articles published during the period 1996 to 2016. As many as twelve core SEE research areas and sixty research trends have emerged after the analysis of titles and abstracts of research articles. Semantic linking between sixty specific research trends and twelve core areas has been identified and presented. The review has been undertaken systematically keeping in view the guidelines

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<http://dx.doi.org/10.1016/j.infsof.2017.06.002>

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Article

# Potential of Livestock Generated Biomass: Untapped Energy Source in India

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Received: 9 May 2017; Accepted: 20 June 2017; Published: 25 June 2017

**Abstract:** Modern economies run on the backbone of electricity as one of major factors behind industrial development. India is endowed with plenty of natural resources and the majority of electricity within the country is generated from thermal and hydro-electric plants. A few nuclear plants assist in meeting the national requirements for electricity but still many rural areas remain uncovered. As India is primarily a rural agrarian economy, providing electricity to the remote, undeveloped regions of the country remains a top priority of the government. A vital, untapped source is livestock generated biomass which to some extent has been utilized to generate electricity in small scale biogas based plants under the government's thrust on rural development. This study is a preliminary attempt to correlate developments in this arena in the Asian region, as well as the developed world, to explore the possibilities of harnessing this resource in a better manner. The current potential of 2600 million tons of livestock dung generated per year, capable of yielding 263,702 million m<sup>3</sup> of biogas is exploited. Our estimates suggest that if this resource is utilized judiciously, it possesses the potential of generating 477 TWh (Terawatt hour) of electrical energy per annum.

**Keywords:** biogas; cows dung; electrical energy; India; livestock

## 1. Introduction

Indiscriminate consumption of fossil fuels to meet energy demand for the burgeoning human population world-wide, especially in high population density nations, is primarily responsible for three quarters of the total world figures for greenhouse gas (GHG) generation [1,2]. The role of GHG as the main contributor to global warming poses a challenge to all life forms on the planet and it is now recognized as a distinct obstacle in the sustainability and living conditions of future generations [3,4]. The high growth rate of the human population and tendencies towards urbanization during the last few decades have raised energy demand which is likely to grow by 25% (700 Quadrillion British Thermal Units) of the present figure, by the year 2040 [5]. In order to fulfill this expected rise in energy demand, alternative sources need to be identified and tapped due to the now recognized likelihood of the exhaustion of fossil fuels. It therefore becomes essential that the best available source of green energy be identified, with a premise that it should be sustainable, should possess the capability of being replenished consistently, and the process should be both natural and bio-friendly [6,7]. If the focus is shifted to a regional level in the Asia-Pacific region, the Indian sub-continent is a likely candidate to explore such possibilities due to the qualifying criteria of being a land mass of varied flora and fauna which can generate enough biomass for the investigation being conducted. India is the world's seventh largest land-mass spreading over 328 million hectares and is expected to become the most populous nation of the world by the year 2025 [5,8]. Politically, India is divided into 35 provinces and union-territories (UTs). India has six main climatic sub-types, ranging from deserts in the west,





## NEURAL BASED ALGORITHM FOR FAULT DETECTION IN A TRANSFORMER

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### Abstract

To find out the incipient power transformer fault symptom diagnosis, a successful adaptation of the neural based algorithm using artificial neural network (ANN) is presented in this paper. A neuron based encoding technique is applied to improve the accuracy of classification, which removed redundant input features that may be confusing the classifier. Experiments using actual data demonstrated the effectiveness and high efficiency of the proposed approach, which makes operation faster and also increases the accuracy of the classification. Five gases namely hydrogen, ethane, methane, acetylene and ethylene are chosen as inputs. Nine output codes for the different type of faults such as partial discharge of low energy, partial discharge of high energy, low energy discharge, high energy discharge, thermal

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Conference held during April 8-9, 2016 at Lovely Professional University, Punjab, India.  
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# Applications of Multi-criteria Decision Making in Software Engineering

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**Abstract**—Every complex problem now days require multi-criteria decision making to get to the desired solution. Numerous Multi-criteria decision making (MCDM) approaches have evolved over recent time to accommodate various application areas and have been recently explored as alternative to solve complex software engineering problems. Most widely used approach is Analytic Hierarchy Process that combines mathematics and expert judgment. Analytic Hierarchy Process suffers from the problem of imprecision and subjectivity. This paper proposes to use Fuzzy AHP (FAHP) instead of traditional AHP method. The usage of FAHP helps decision makers to make better choices both in relation to tangible criteria and intangible criteria. The paper provides a clear guide on how FAHP can be applied, particularly in the software engineering area in specific situations. The conclusion of this study would help and motivate practitioners and researchers to use multi-criteria decision making approaches in the area of software engineering.

**Keywords**—Multi-criteria Decision Making; Analytic Hierarchy Process; Fuzzy AHP; Software Engineering

## I. INTRODUCTION

Multi-Criteria decision making (MCDM) approaches take decisions in the presence of multiple, usually conflicting, criterion. MCDM approach handles both quantitative and qualitative choices and is able to combine the historical data and expert opinion by quantifying subjective judgement [1]. There are many MCDM models which include Analytic Hierarchy Process (AHP), PROMOTHEE, ELECTRE, TOPSIS, VIKOR each having different algorithm [2]. Most widely used MCDM technique is AHP, developed by Saaty and inspired by the intelligent behaviour of human beings. Since judgments given by decision makers are relative, any change in the relative values of the choices may significantly change the weights of affected choices, resulting in a problem known as Rank Reversal [3]. The problem of imprecision and subjectivity in the weight calculation process is not handled in AHP and these problems can be overcome by using Fuzzy AHP. Software Engineering has always been an area of concern for researchers because of its real time applications in the era of computer science. In most of the applications the final decision is dependent on the outcome ranking of alternatives in respective to criterion [4]. Software development and evolution is characterized by multiple objectives and constraints [5]. Nowadays the problems have become more and more complex and depend upon multiple factors. So applying multi-criteria decision making (MCDM) approaches for solving complex problems dependent

on multiple aspects is required than simple linear algorithmic approaches. This paper focuses on AHP, FAHP and their comparison by taking a working example and how FAHP is widely accepted approach in the field of software engineering. The next section discusses about AHP, Fuzzy AHP process in detail. The further section summarizes the different application areas in which Fuzzy AHP can be used. Then an example illustrates the use of Fuzzy AHP in selecting the quality model. The last section concludes and gives the future scope of the paper.

## II. MULTI-CRITERIA DECISION MAKING APPROACHES

### A. Analytic Hierarchy Process

Analytic Hierarchy Process (AHP) is an MCDM approach, proposed by Saaty [6], for handling multi objective problems. This approach selects best alternatives based on criterion [7]. AHP is well structured mathematical approach uses consistent matrices and their associated eigenvectors to produce relative weights[8]. AHP combines historical data and expert opinion by quantifying subjective judgement [9]. It structures the given problem as a hierarchy, with required goal as parent node and criteria for assessing it are placed in levels below it. Weights are assigned to each node and many pairwise comparisons and matrix multiplications are made assessing the relative importance of these criteria. The end result of this method is to provide a formal, systematic means of extracting, combining, and capturing expert judgements and their relationship to analogous reference data [10].


The steps followed by AHP for concluding the relative rankings of alternatives are as follows [3]:

- 1) Decomposition of problem to required goal, criterion, alternatives.
- 2) Read the decision values/variable.
- 3) Creating the reciprocal matrix for the pairwise comparisons of criterion.
- 4) Find Eigen values and calculate the Eigen vector for computing weights.
- 5) Find the consistency index of the weight.
- 6) Repeat the steps from 1 to 5 for each value criterion.
- 7) Calculate the overall weight vector of the hierarchy.
- 8) Infer the alternative based on the overall weight vector.



Article

# Assessment of Capacitance for Self-Excited Induction Generator in Sustaining Constant Air-Gap Voltage under Variable Speed and Load

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Received: 1 September 2018; Accepted: 17 September 2018; Published: 20 September 2018



**Abstract:** The concept of a Self-Excited Induction Generator (SEIG) has introduced the concept of the placement of an induction machine for power generation in an isolated mode with external capacitance. The produced output voltage and generated frequency in an SEIG greatly depends on speed, load, and terminal capacitance. To maintain constant air-gap voltage against a varying speed and load, a corresponding supply of reactive power through capacitors is needed. The selection of the required capacitance while there is continuous variation of vital parameters needs a rigorous random-selection method. In this paper, an intelligent selection of suitable additional capacitance has been made by using the Fuzzy Logic Technique for a Three-Phase 5.0 HP SEIG. Additional capacitance in the range of 14.79–22.47  $\mu\text{F}$  is compulsory under a varying load of 427–101 ohms, and additional capacitance in the range of 13.70–22.59  $\mu\text{F}$  is essential for a varying speed of 1349 to 1672 RPM. With this promising result, we propose the implementation of this intelligent technique in place of analytical and standard methods for capacitance selection.

**Keywords:** self-excited induction generator; load; speed; capacitance

## 1. Introduction

The indiscriminate utilization of fossil fuels to meet the ever-growing energy demand of the worldwide population has in all increased the total global figure for the production of greenhouse gases (GHG) by three quarters [1]. These GHG emissions are a major contributor to global warming and stand as the biggest hurdle for upcoming generations. The changing scene of ultramodern living and a manyfold population rise has raised energy demands. To fulfill these rising energy demands, alternative sources of energy need to be identified and exploited on a large scale. It has also necessitated the need for a sustainable and green energy source. Renewable-energy sources, such as solar, wind, biomass, and hydro are sustainable, environmentally safe, and green sources of energy. Additionally, the recent development of deregulation and decentralization of the power-generation system has given birth to the concept of distributed generation by using renewable-energy resources [2]. Commissioning distributed generation through the exploitation of renewable energy resources near load centers requires a conversion-efficiency device like a generator. Usage of an induction machine as generator is well-received as a renewable energy resource [3–7]. Induction machines, coupled to an external prime mover and running at a speed above the synchronous speed with grid frequency, are capable of generating power at a negative slip. In the negative-slip region, the induced torque direction is reversed, the machine starts behaving as an induction generator, and it draws a current that lags behind the voltage with an angle greater than  $90^\circ$  [8]. This indicates the outflow of real power from the machine, but to maintain real and reactive power balance, the machine needs the reactive power.





Article

# Potential of Livestock Generated Biomass: Untapped Energy Source in India

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Received: 9 May 2017; Accepted: 20 June 2017; Published: 25 June 2017

**Abstract:** Modern economies run on the backbone of electricity as one of major factors behind industrial development. India is endowed with plenty of natural resources and the majority of electricity within the country is generated from thermal and hydro-electric plants. A few nuclear plants assist in meeting the national requirements for electricity but still many rural areas remain uncovered. As India is primarily a rural agrarian economy, providing electricity to the remote, undeveloped regions of the country remains a top priority of the government. A vital, untapped source is livestock generated biomass which to some extent has been utilized to generate electricity in small scale biogas based plants under the government's thrust on rural development. This study is a preliminary attempt to correlate developments in this arena in the Asian region, as well as the developed world, to explore the possibilities of harnessing this resource in a better manner. The current potential of 2600 million tons of livestock dung generated per year, capable of yielding 263,702 million m<sup>3</sup> of biogas is exploited. Our estimates suggest that if this resource is utilized judiciously, it possesses the potential of generating 477 TWh (Terawatt hour) of electrical energy per annum.

**Keywords:** biogas; cows dung; electrical energy; India; livestock

## 1. Introduction

Indiscriminate consumption of fossil fuels to meet energy demand for the burgeoning human population world-wide, especially in high population density nations, is primarily responsible for three quarters of the total world figures for greenhouse gas (GHG) generation [1,2]. The role of GHG as the main contributor to global warming poses a challenge to all life forms on the planet and it is now recognized as a distinct obstacle in the sustainability and living conditions of future generations [3,4]. The high growth rate of the human population and tendencies towards urbanization during the last few decades have raised energy demand which is likely to grow by 25% (700 Quadrillion British Thermal Units) of the present figure, by the year 2040 [5]. In order to fulfill this expected rise in energy demand, alternative sources need to be identified and tapped due to the now recognized likelihood of the exhaustion of fossil fuels. It therefore becomes essential that the best available source of green energy be identified, with a premise that it should be sustainable, should possess the capability of being replenished consistently, and the process should be both natural and bio-friendly [6,7]. If the focus is shifted to a regional level in the Asia-Pacific region, the Indian sub-continent is a likely candidate to explore such possibilities due to the qualifying criteria of being a land mass of varied flora and fauna which can generate enough biomass for the investigation being conducted. India is the world's seventh largest land-mass spreading over 328 million hectares and is expected to become the most populous nation of the world by the year 2025 [5,8]. Politically, India is divided into 35 provinces and union-territories (UTs). India has six main climatic sub-types, ranging from deserts in the west,



# Computation of Power Transformer Reactance using Finite Element Method

Vibhuti, Genius Walia, Deepika Bhalla

**Abstract:** The reactance of the transformer windings is an important component for the design which has a direct effect on its operation. Reactance is used for computation of not only the transformer equivalent circuit parameters and also for designing its protection. The Roth's method, Rabin method, method of images, and classical methods are the traditional methods used for its calculation. The finite element method can be used for the calculation of transformer reactance. In the industrial revolution 4.0 all manufactured transformers would be evaluated through their 3D design and performance analyzed by computational methods. In this work the reactance calculated by the finite element method has been compared to that calculated by the classical method. The calculated values of energy stored in the windings and other parts and the reactance can be found.

**Keywords:** Finite Element Method, Leakage Reactance, Transformer, Windings

## I. INTRODUCTION

The leakage impedance of a transformer comprises of resistive and reactive components is one of the most significant details that have a substantial impact on the overall design. The reactance of a transformer is an important specification. While designing a transformer different method namely; Roth's method, Rabin's method, method of images, and classical methods are used. These methods are assumption based and have considered simple configuration. The finite element method (FEM), a computational method can be used to calculate the of transformer winding reactance. The FEM is also known as the coupled field method, is the most ideal mathematical technique because of its geometric complexity, for handling nonlinearity. This method can easily solve the problems that involve the coupling of electromagnetic fields. The method can be used to calculate the self-inductance and mutual-inductance between turns and winding sections, dielectric stresses in insulation. 3D finite element analysis simulation is used to geometry model [1], stray losses [2] and electromagnetic forces [3]. To calculate the parasitic capacitance of secondary winding [4], the forces in the winding during inter turn short circuit faults [5], FEM is used.

Revised Manuscript Received on March 04, 2020.

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## II. LEAKAGE REACTANCE

The leakage reactance in a transformer is because all the flux does not confine inside the core. In the transformer, both the primary winding and the secondary winding overlap the structure of the core and net magnetic flux is produced by these windings. An ideal transformer all the flux in the core links both the primary winding and the secondary winding. In a practical transformer, not all the flux produced by the one winding links the other winding. The difference between the total flux linking with the primary and the useful mutual flux linking both the windings is called the primary leakage flux. Similarly, there exists a secondary leakage flux. With each cycle of the power supply, energy is alternately stored and discharged in the magnetic field. The leakage flux is represented by reactance of the primary and secondary. The primary winding reactance can be transferred to the secondary side and vice-versa, using the turn-ratio. Practically, the reactance of a transformer is found by performing the short-circuit test on the low voltage side. The leakage reactance in theory is calculated by classical methods. Work has been carried out for computation reactance using classical methods to improve the design [6].

## III. APPROACHS FOR LEAKAGE REACTANCE CALCULATION

The method used for the calculation of the leakage flux that is represented as of the windings of a transformer are; Roth's method, Rabin's method, method of images, and classical methods.

### A. Rabin's Method

In this method, we assumed that current density ( $J$ ) depends on the axial position. This method uses single Fourier series. The magnetic vector potential  $A$ , is given by the expression:

$$\nabla^2 A = -\mu J \quad (1)$$

Rabin's method is more suitable to solve the Poisson's equation using cylindrical coordinates. The equation in cylindrical coordinates is:

$$\frac{\partial^2 A_\theta}{\partial r^2} + \frac{1}{r} \frac{\partial A_\theta}{\partial r} - \frac{A_\theta}{r^2} + \frac{\partial^2 A_\theta}{\partial z^2} = -\mu J_\theta \quad (2)$$

### B. Roth's Method

This method is used for calculating the leakage reactance of windings that have asymmetrical arrangement. The method is based on a doubled Fourier series and is relevant to both uniform and non-uniform distributions of main of windings.

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# Analyzing short circuit forces for double layer helical LV winding using FEM

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## Abstract

The low voltage (LV) winding in medium and high capacity transformers where current rating is high and number of turns is low is generally of helical type. The helical windings have inherent asymmetry and during short circuit, the asymmetry results in very large magnitude electromagnetic forces. In this paper, the short circuit forces in double layer helical LV winding are computed using finite element method with an objective of finding the radial and axial components of forces in windings and identify areas of high stresses that can find the likely reason of failure. All computations are carried out for a 3 legged 630kVA, 11000/433V transformer. The effect of asymmetry due to center tapping is also considered

*Keywords:* Electromagnetic forces; Finite element method; Helical winding; Power transformer; Short circuit forces

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## 1. Introduction

Transformer is a critical component of a power system, and reliability of the system depends on its proper operation and design. The mechanical stresses that occur due to short circuit can damage the insulation, deform the windings and core, thus cause transformer failure that result in costly outages. Proper design of windings and insulation can reduce the in-service failure of the transformer. The knowledge of the magnitude of short circuit forces helps the design engineer manage the mechanical stress. If the design is such that the ability to withstand short circuit forces is poor, then the seed defect in the design would cause transformer failure during testing or soon after installation. For a particular design, if the region where forces would act during short circuit is known, then proper mechanical support and insulation can be provided to prevent failure. The failure of transformer could be due to radial or axial component of the electromagnetic force produced during short circuit. Bucking of low voltage (LV) winding, and stretching of high voltage (HV) winding are caused due to radial force; while conductor tilting and axial bending between spacers are due to axial force.

During physical inspection of transformers that have failed due to passing of short circuit current, it is observed that the yoke gets separated from the limbs, at times, the insulation in the end turns is damaged. The start and end of a transformer

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## Photo-Voltaic based Smart Irrigation Cart

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**Abstract.** The need of energy is increasing dramatically in all sectors of life. The cost-effective solution be the answer for all our energy requirements. Renewable energy is the best possible solution to replace conventional energy sources, both in terms of cost and environmental issues. While considering Indian farming system, electricity is a source of problem behind fruitful irrigation of the land. PV based smart irrigation cart can the solution for electricity problems faced by Indian farming where there is no electricity. The proposed approach consists of PV powered water pump system installed on a mobile cart for irrigating the field. The present work is based on the concept of “pay for power” where an independent source of power will be developed and utilized by the farmers for their irrigation purpose. It will also reduce the dependency of the farmers on conventional electrical companies and further reduces the cost of farming.

### 1. Introduction

The main hurdle towards the development of Indian agriculture sector is intermittent supply of electricity in rural areas. India’s rural system is still in developing phase, with major sections of its populace are still waiting for un-interrupted electric supply for their irrigation work. In an isolated sector such as the rural zones, the use of the RES mainly Photo-Voltaic (PV) provides better solution to obtain required electric energy for their applications to both the domestic and agriculture sectors [1,2]. Hence, in this scenario stand-alone PV systems are obtaining an increasing interest and becoming very competitive solution in India, because excess sunny days are available throughout the year.

Now-a-days PV based farming irrigation systems are generally employed for farming, livestock and water supplies at low scale level [3]. The main applications of PV standalone systems in remote or rural areas are for water pumping where considerable amount of solar radiations are available and have no access to electricity [4]. An effective option must ensure that the PV systems to operate on the Maximum Power Point Tracking (MPPT) concept [5]. Once an initial investment has been made, this green approach for electricity application provides free energy.

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Received July 23, 2020, accepted August 2, 2020, date of publication August 5, 2020, date of current version August 19, 2020.

Digital Object Identifier 10.1109/ACCESS.2020.3014288

# Power Quality Assessment of Distorted Distribution Networks Incorporating Renewable Distributed Generation Systems Based on the Analytic Hierarchy Process

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This work was supported by the Deanship of Scientific Research at Majmaah University under Project RGP-2019-27.

**ABSTRACT** The proliferation of not only power electronics supported consumption technologies but also the expansion of the renewable-based distributed generation (DG) systems has given rise to severe power quality (PQ) phenomena in consort with the offered technical, economic and environmental benefits under deregulated environment. The forthcoming complexity of distribution power networks caused by incorporation of a large number of DG units in deregulated electricity market unquestionably makes PQ assessment procedure a quite cumbersome one. In present work, an analytic hierarchy process (AHP) inspired methodology is proposed for PQ assessment of distorted distribution power systems under the presence of renewable-based DGs. The proposed PQ assessment approach is based on formulating a unified power quality index (UPQI) for assessing the overall PQ performance of individual buses of the network along with the entire distribution network (DN) considered taking four PQ phenomena, viz. voltage harmonics, voltage sags, voltage unbalance and steady-state voltage profile at each bus into account. The application significance of the presented methodology is established by utilizing it on an IEEE 13 bus test distribution system modified through incorporating the nonlinear loads and DG systems based on three types of RES namely, photovoltaic (PV), wind and fuel cell, in MATLAB/Simulink environment. The results achieved validates the efficacy of the presented approach in assessing the overall PQ performance of each of the buses and the entire DN along with benchmarking it with respect to the threshold level of unity. Based on obtained results, also the comparative analysis is performed among PQ performances of DN with selected three RES based DGs. Moreover, the impact of the employing the custom power devices (CPDs) as well as excessive penetration level of renewable energy over PQ performance of distribution network, are also investigated by the application of the formulated index.

**INDEX TERMS** Analytic hierarchy process, distributed generation, harmonics, power quality, unified power quality index.

## ABBREVIATIONS

RES Renewable Energy Source  
PQ Power Quality  
AHP Analytic Hierarchy Process  
UPQI Unified Power Quality Index  
DN Distribution Network

DG Distributed Generation  
PV Photovoltaic  
CPD Custom Power Device  
DER Distributed Energy Resource  
FRT Fault Ride Through  
HC Hosting Capacity  
BVD Background Voltage Distortion  
EPS Electric Power System  
FCA Fuzzy Cluster Analysis

The associate editor coordinating the review of this manuscript and approving it for publication was Alba Amato.

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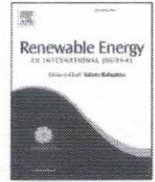




Contents lists available at ScienceDirect

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## Market-based participation of energy storage scheme to support renewable energy sources for the procurement of energy and spinning reserve



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### ARTICLE INFO

#### Article history:

Received 22 August 2017  
Received in revised form 29 October 2018  
Accepted 4 December 2018  
Available online 7 December 2018

#### Keywords:

Ancillary services  
Energy procurement cost  
Energy storage schemes  
Reserve procurement cost  
Spinning reserve markets  
Virtual power plants

### ABSTRACT

Energy Storage Scheme (ESS) is of great importance to realize energy management and to optimally utilize Renewable Energy (RE) integration in the electricity system. An increasing exploitation of RE in electricity system raises the concern about the need for Ancillary Services (AS) in a power system. These services are required for maintaining the reliability and security of the supply. This paper proposes a market-based participation of ESS to support large-scale RE penetration for the procurement of energy and AS using Virtual Power Plant (VPP) in a deregulated environment. The proposed VPP consists of a pumped-storage system as one of the recognized ESS and Renewable Power Producers (RPPs). This optimization problem is formulated and solved using an optimal power flow technique which considers network constraints and power flow limits. Spinning Reserve (SR) as one of the main AS is considered in this paper, which is procured under Spinning Reserve Market (SRM). The ability of the proposed approach to provide both energy and SR is tested on 3 case studies and demonstrated by considering a modified IEEE-30 bus test system. Results show that the VPPs can play a significant role in increasing the penetration of RE for the procurement of energy and AS.

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### 1. Introduction


Recent years have witnessed various countries across the globe deploying a mix of several systems for electricity generation purposes. The reliance on fossil fuels results in most significant threats to environmental pollution, including Green House Gas (GHG) emissions that result in worst and irreversible harm to the climate. Non-diminishing RE represents a possible alternative to reduce GHG emissions, improve energy security and decrease dependency on diminishing supplies of fossil fuels for energy generation [1]. The penetration of Renewable Energy Source (RES) in the electrical system is gradually increasing, and the share of Conventional Energy Sources (CESs) like coal, gas, and oil is undergoing a declining stake in the primary inputs to the generation mix [2]. At present, RE represents the only clean and constantly growing source of

electricity generation worldwide. The year 2015 was an extraordinary year for RE with the largest global capacity additions of around 213 TWh [3]. The long-lasting RESs produce more eco-friendly power but put greater pressure on power system operations and the electricity markets due to their variable and intermittent nature [4].

Due to enormous growth in energy demand in recent years, power system equipment needs to run at their full capacities. This possibly will lead to unplanned outages and failure of the equipment. To match generation and demand on a real-time basis, some sort of services are required that can maintain reliability and security of the supply. These so-called services are commonly known as ancillary services [5]. These are simply classified into frequency control services (like regulation, load following, operating reserves), voltage control services (through reactive power support) and emergency services (by black-start services) and are considered as main AS in almost every electricity market [6].

Special consideration in this paper is given to the procurement of capacity based Operating Reserve (OR) that include Spinning

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## Simulation Based Elevator Group Control System for Multi-Storey Building

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(Received April 29, 2018; Accepted November 18, 2018)


### Abstract

In this work fuzzy logic based controller for Elevator Group Control System (EGCS) is proposed. The most complex problem is to control the multi-elevator in a multi-storey building and there are different approaches to solve the problem. The approach used based on the Simulink model and the fuzzy logic controller which is proposed to choose the most appropriate elevator for a hall call generated by passenger/user. The simulation was carried out by giving the input which was used to calculate the input for fuzzy logic controller. The data obtained from the simulation model and the input source provided to the fuzzy based controller priority of each elevator car can be calculated. The maximum priority elevator car is responded for its hall call operation. The input was based on hall call assignment method. This work can assist in analyzing the performance of the Elevators.

**Keywords-** Fuzzy logic controller, Simulink, Hall call assignment method, Elevator group control system.

### 1. Introduction

An EGCS is used for automation of three or more elevators in a group. An EGCS is useful in reducing the waiting time and riding time and to provide an increased quality of service to passengers. The EGCS consists of various parameter calculations such as waiting time, riding time, travelling distance, hall call area weight, destination area weight. This parameter acts as the input to the Fuzzy Logic Controller (FLC) (Zadeh, 1973; Lee, 1990). In general, EGCS uses the hall call assignment method (HCAM) which designates elevators in response to a passenger's call. In this case, the EGCS selects the nearly available elevator to the request of the passenger. The HCAM assigns a new hall call to the elevator when the user/passenger gives their destination details before entering in the elevator car. This method was very helpful as it reduces the ambiguity of the destination and reduces the fake calls which were assigned by the passengers after entering the elevator car. The area-weight is an important parameter and affects the evaluation function values of elevators. In this work, the simulation method is implemented. In

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# Mixed GA-OPF based optimal procurement of energy and operating reserve in deregulated environment

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**Abstract.** Ancillary Services (AS) plays a vital role in a deregulated environment because these services act as the frontier of a power system. It helps to maintain the quality and safety of the supply. Operating Reserve (OR), as an important AS, has been considered in this work. This paper proposed a mixed Genetic Algorithm (GA)-Optimal Power Flow (OPF) mechanism can act as an effective tool for procurement of different services like energy and AS. The sequential clearing technique has been considered for procurement of Energy and OR an objective of cost minimization. Herein, the EM is cleared first in Energy Market (EM) followed by clearing of Operating Reserve Market (ORM). The proposed approach for obtaining the required service using mixed GA-OPF approach has been investigated by considering modified IEEE-30 bus test system.

**Keywords:** Electric power deregulation, genetic algorithm, optimal power flow, operating reserve, disaggregated approach, energy and AS market

## Abbreviations

|      |                                      |
|------|--------------------------------------|
| AC   | Available Capacity                   |
| AS   | Ancillary Services                   |
| ARC  | Available Reserve Capacity           |
| EM   | Energy Market                        |
| FM   | Forward Markets                      |
| GA   | Genetic Algorithm                    |
| IDM  | Intra-Day Markets                    |
| ISO  | Independent System Operator          |
| JOD  | Joint Optimization Dispatch          |
| FERC | Federal Energy Regulatory Commission |
| MOD  | Merit Order dispatch                 |

|       |                                 |
|-------|---------------------------------|
| OPF   | Optimal Power Flow              |
| ORM   | Operating Reserve Market        |
| RTM   | Real-Time Market                |
| SQD   | Sequential Dispatch             |
| TMNSR | Ten Minute Non Spinning Reserve |
| TMOR  | Thirty Minute Operating Reserve |
| TMSR  | Ten Minute Spinning Reserve     |

## 1. Introduction

To enhance competition, power system utilities have participated in the process of restructuring. This reformation of the power sector brought significant changes in power system operation [17]. Figure 1 shows the disaggregation of the vertically

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# Mixed GA-OPF based prioritized optimal location and rating of wind power generation in deregulated electricity market

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**Abstract.** Due to the liberalization of the electricity market, the traditional concepts and practices of the electrical systems have resulted in the introduction of Competitive Electricity Market (CEM). The recognition of CEM provides special consideration for the development of Renewable Energy (RE) throughout the world. The paper presents a mixed Genetic Algorithm (GA) and Optimal Power Flow (OPF) based model for determination of the optimal location and rating of Wind Power Generation (WPG). The optimization algorithm has been formulated and solved while considering the procurement cost minimization for obtaining the required energy by optimally locating the WPG in the system. The proposed mixed GA-OPF approach has been successfully applied to the modified IEEE 30-bus test system. The proposed algorithm also resulted in the prioritized list of optimal locations of WPG in the system.

**Keywords:** Competitive electricity market, wind power generation, genetic algorithm, optimal power flow, procurement cost, optimal location

## 1. Introduction

With the rapid increase in the energy demands, more energy resources are required to follow the energy requirements, if we meet this demand for coal fired thermal power plants in environmental pollution and global warming are the major consequences. Renewable Energy Sources (RES) plays a vital role in the accomplishment of an electricity sector. It largely aims to improve service standards, increase system efficiency, and to develop competitive market. It has altered the customary operation and requirement of

utilities in complex customs, and had huge impacts on ecological, political, and societal state of affairs for any country [1]. Wind-based generation capacity accounted for around 75% of the total installed renewable energy generation capacity all over the world. Wind energy is an indigenous and virtually unlimited source of electricity generation.

In present scenario, the earlier Vertical Integrated System (VIS) which was the sole authority that looks into the functions related to electricity. Now, it is categorized into three major components like GENCOs for generations, TRANSCO for transmission, and DISCOs for distribution of electrical power [2].

RES is progressively being considered as one of the notable participants in CEM. Due to the global increase of oil prices and lower accessibility of fine

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# Simultaneous optimization of renewable energy based pumped storage scheme in energy and ancillary services market under deregulated power sector

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**Abstract.** The power sector is experiencing comprehensive changes in its regulatory structure, sensing advancement and also prone to system security threats. To make the system more reliable the use of Ancillary Services (AS) become a must. The AS maintains the system security and reliability. With deregulation, the integration of Renewable Energy Sources (RES) in the power system has increased. To utilize RES at the maximum extent, the use of Energy Storage Systems (ESS) is required. ESS like Pumped Storage Plant (PSP) mainly adds great value to support renewable utilization. This paper proposes the simultaneous dispatch of energy and AS market such that the total procurement cost is minimized. The procurement of Operating Reserve (OR) as one of the principal AS is considered in the present work. The optimization problem is formulated and solved using Optimal Power Flow (OPF) technique. RES like Wind Power (WP) and Photo-Voltaic (PV), PSP as ESS with other conventional power generation units are considered to provide energy and AS. Four different cases considering various combinations of energy providers in the optimization problem have been studied and compared using modified IEEE-39 test bus system.

**Keywords:** Deregulated power sector, ancillary services, renewable energy sources, energy storage scheme, simultaneous optimization, operating reserve

## 1. Introduction

The electrical power industry around the world is meeting increasing demands for electricity in a competitive framework. Restructuring of power utilities are seen leading to deregulation of the power sector.

The power industry has been a natural monopoly for a century. The monopoly had a vertically integrated structure comprising the generation, transmission and distribution services. Since the 1980's the power industry is undergoing rapid change in its operating framework.

The framework has been serving the people well and maintained the system stability too. The change in the framework is allowing competition between the generating companies to establish a power market in

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Contents lists available at ScienceDirect

## Renewable and Sustainable Energy Reviews

journal homepage: [www.elsevier.com/locate/rser](http://www.elsevier.com/locate/rser)

## An international experience of technical and economic aspects of ancillary services in deregulated power industry: Lessons for emerging BRIC electricity markets

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## ARTICLE INFO

## Keywords:

Ancillary services market  
Assessment mechanism  
Competitive electricity market  
Renewable energy sources  
Trading mechanism

## ABSTRACT

An introduction of competition in electricity markets and the substantial growth in the capacity of transactions significantly complicates the task of sustaining security and dependability of an electrical arrangement. This responsibility is dedicated to Ancillary Services (AS) that, in perspective to market liberalization, is the accountability of the System Operators (SO) to secure the requisite level of quality and safety. In the liberalized environment, AS are disaggregated from the energy generation, and can be obligated or compensated under market processes. SO seeks specific ways to define, procure and implement such services by managing active power for adjusting the frequency and reactive power for sustaining sufficient voltage profile throughout the arrangement. A comprehensive analysis of several techno-economical aspects of AS in liberalized electricity markets of a developed economy and emerging economies has been reviewed in this work. While attending the

**Abbreviations:** ABT, Availability Based Tariff; ACP, Area Clearing Price; AGC, Automatic Generation Control; ALR, Automatic Load Rejection; APFC, Assigned Primary Frequency Control; APR, Active Power Reserves; AS, Ancillary Services; ASFC, Automatic Secondary Frequency Control; ASM, Ancillary Service Market; ASMP, Ancillary Service Marginal Prices; ASP, Ancillary Services Providers; AVC, Automatic Voltage Control; BA, Balancing Authority; BAS, Basic Ancillary Services; BESS, Battery-based Energy Storage Scheme; BM, Balancing Market; BPR, Basic Peak Regulation; BRIC, Brazil, Russia, India, and China; BRPR, Basic Reactive Power Regulation; BS, Black Start; BSAS, Black Start Ancillary Services; BSCS, Black Start Capability Services; BSS, Black Start Service; CAS, Compensated Ancillary Services; CCA, Competitive Capacity Auctions; CCM, Co-optimized Commitment Mechanism; CCEE, Chamber of Electric Energy Trade; CCGP, Combined Cycle Power Plant; CERC, Central Electricity Regulatory Commission; CM, Capacity Market; CER, Conventional Energy Resources; CLPIPL, China Light and Power India Private Limited; CPR, Compensable Peak Regulation; CR, Contingency Reserves; CRAF, Contingency Reserve Adjustment Factor; CRPR, Compensable Reactive Power Regulation; CSP, Concentrated Solar Power; CWEM, Competitive Wholesale Electricity Market; DA, Day Ahead; DAEM, Day Ahead Energy Market; DAM, Day Ahead Markets; DA-RUC, Day Ahead Reliability Unit Commitment; DASR, Day Ahead Scheduling Reserve; DR, Demand Resources/Response; DSR, Demand Side Resources; ED, Economic Dispatch; EV, Electric Drive Vehicles; FCB, Fast Cut Back; FCM, Forward Capacity Market; FERC, Federal Electricity Regulatory Commission; FGMO, Free Governor Mode of Operation; FM, Forward Markets; FR, Frequency Regulation; FRAS, Frequency Regulation Ancillary Services; FSAS, Frequency Support Ancillary Services; FTR, Financial Transmission Rights; GGR, Generator Governor Response; GHG, Green House Gas; GIPCL, Gujarat Industries Power Company Limited; HAM, Hour-Ahead Markets; HEP, Hydro Electric Plant; HPS, Hydro Power Station; JOD, Joint Optimization Dispatch; IDM, Intra Day Markets; IEGC, Indian Electricity Grid Code; IEX, Indian Energy Exchange; ISTS, Inter State Transmission System; JOD, Joint Optimization Dispatch; LF, Load Following; LFC, Load Frequency Control; LMP, Locational Marginal Price; LTA, Long Term Agreements; LTC, Load Tap Changers; MCP, Market Clearing Price; MCPE, Market Clearing Prices for Energy; MPT, Market Place Timelines; MO, Market Operator; MOD, Merit-Order Dispatch; M-VCAS, Mobile Voltage Control Ancillary Services; NBS, Non-Black Start; NEP, National Electricity Policy; NERC, North American Electric Reliability Corporation; NERC-CPC, NERC Control Performance Criteria; NLDC, National Load Dispatch Centre; NSR, Non Spinning/Synchronized Reserve; NTPC, National Thermal Power Corporation; OR, Operating Reserve; ONS, Operator of the National Electricity System; PEV, Plug-in Electric-drive Vehicles; PFC, Primary Frequency Control; PFR, Primary Frequency Regulation; PGL, Peak Generator Load; PLF, Plant Load Factor; PR, Primary Reserve; PSESS, Pumped-Storage based Energy Storage Scheme; PSR, Power System Restoration; PV, Photo-Voltaic; PX, Power Exchanges; PXIL, Power Exchange India Limited; QR, Quaternary Reserve; RBA, Rational Buyer's Algorithm; RES, Renewable Energy Sources; RGPPL, Ratnagiri Gas and Power Private Limited; RIPS, Regulation Interval Performance Score; RLDC, Regional Load Dispatch Centre; RPC, Regional Power Committees; RPP, Renewable Power Producers; RPS, Renewable Portfolio Standard; RPSS, Reactive Power Support Services; RR, Regulation/Replacement Reserves; MPT, Market Place Timelines; RSS, Reactive Support Service; RT-LMP, Real Time Locational Marginal Price; RTC, Real Time Commitment; RTD, Real Time Dispatch; RTM, Real Time Market; RTO, Regional Transmission Operator; SC, Scheduling Coordinators; SCED, Security Constrained Economic Dispatch; SCUC, Security Constrained Unit Commitment; SD, Sequential Dispatch; SO, System Operators; SP, System Producers; SPP, Southwest Power Pool; SLDC, State Load Dispatch Centre; SR, Spinning/Synchronized Reserves; NERC-CPC, NERC Control Performance Criteria; SRC, Spinning Reserve Capacity; SERC, State Electricity Regulatory Commission; TAM, Term Ahead-Market; TAF, Three-year Ahead Forward Capacity; TFC, Tertiary Frequency Control; TMNSR, Ten Minute Non-Synchronized/Non-Spinning Reserve; TMOR, Thirty Minute Operating Reserve; TMRR, Thirty Minute Replacement Reserves; TMSR, Ten Minute Synchronized/Spinning Reserve; TR, Tertiary Reserve; UCTE, Union for the Co-ordination of Transmission of Electricity; UI, Unscheduled Interchange; URS, Un-Requisitioned Surplus; US, United States; VCAS, Voltage Control AS; VCSS, Voltage Control Support Services; VIS, Vertical Integrated Systems; VS, Voltage Support; VSS, Voltage Support Service; WEM, Wholesale Electricity Market; WSSC, Western Systems Coordinating Council

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<https://doi.org/10.1016/j.rser.2018.03.085>

Received 18 September 2016; Received in revised form 26 March 2018; Accepted 26 March 2018  
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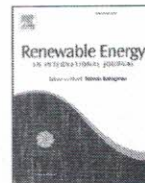




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# Renewable Energy

journal homepage: [www.elsevier.com/locate/renene](http://www.elsevier.com/locate/renene)



## Real time procurement of energy and operating reserve from Renewable Energy Sources in deregulated environment considering imbalance penalties



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### ARTICLE INFO

#### Article history:

Received 30 March 2017  
Received in revised form 23 May 2017  
Accepted 18 June 2017  
Available online 23 June 2017

#### Keywords:

Operating reserve  
Penalty  
Procurement cost  
Renewable power producer  
Sequential dispatch  
Social benefit

### ABSTRACT

Renewable Energy Sources (RES) have prompted an additional burden on power system planners due to their stochastic nature. Hence it increases the need for Ancillary Services (AS) in power system. In deregulated electricity markets, AS has become an important issue because they are necessary for reliable and secure operation of a power system. Operating Reserve (OR), considered in this paper, is a measure of generators ability to increase their output under contingencies. ISO uses this service either for balancing purpose or for replacing the energy that had been scheduled to be provided by the unit that malfunctions. Thus establishing an efficient market for reserve services has become crucial. The premises of this paper is the development of penalty based Short-Term Market (STM) for the procurement of energy and CR. The effects of stochastic behavior of WPP on Social Benefit (SB) and Procurement Cost (PC) are investigated for the development of efficient STM. The proposed approach has been analyzed on IEEE-30 bus test system by implementing a sequential dispatch approach on various market structures. The results obtained under different market scenarios shows that there is a mandated requirement of effective penalty mechanism in order to discourage the imbalance behavior of RPPs.

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### 1. Introduction

Traditional power systems have been dominated by large Vertical Integrated Utilities (VIU) that performs all the activities related to generation, transmission and distribution of electric power within their obliged domain. These bundled utilities generally work under the regulated environment of the government jurisdiction [1]. During the early nineties, various electrical utilities of mostly developed economies have undergone through the unbundling process by changing their way of operation from being VIU to open market systems that consist of three independent components viz. Generation Companies (GENCOs), Transmission Companies (TRANSCO), and Distribution Companies (DISCOs) [2]. The deregulation of power sector provides a fair competition among producers as well as consumers. Unbundling of these utilities primarily

focuses on improving system efficiency, cost minimization by introducing more choices to the utilities by developing competitive markets and, better service to the electrical consumers [3].

In deregulated paradigm, the market existing between suppliers (GENCOs) and retailers (DISCOs) is called the wholesale marketplace. An ISO as an independent authority is appointed for the creation of the set of rules for ensuring sufficient control over producers and consumers for maintaining security and reliability of the electrical system while maximizing market efficiency. The GENCOs sell their energy either through long-term bilateral contracts with DISCOs or by bidding in STM operated by the ISO [4]. The basic bidding structure in STM is shown in Fig. 1.

Substantial unbundling of products and services is to be expected under restructuring process. Surely electricity provided at different times will be treated differently. It also raises the issue of AS that could be separated or bundled depending on the economics of supply and the nature of customer demand [5]. AS has become an important issue because they are necessary for the reliable and secure operation of a power system. It is essential to procure these

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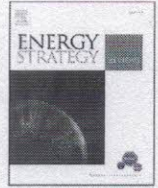




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# Energy Strategy Reviews

journal homepage: [www.ees.elsevier.com/esr](http://www.ees.elsevier.com/esr)



## Review

# Renewable energy sources as a new participant in ancillary service markets



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### ARTICLE INFO

#### Article history:

Received 16 February 2017  
Received in revised form  
10 August 2017  
Accepted 12 September 2017  
Available online 22 September 2017

#### Keywords:

Ancillary services  
Energy  
PV power  
Renewable energy sources  
Wind power

### ABSTRACT

In a liberalized electricity market, an important and major task of System Operator (SO) is to support the transactions of power and to match required demand-supply balance. To maintain this balance, Ancillary Services (AS) are required that ensures transmission of power while maintaining reliable operation and ensuring the required degree of quality and safety. Presently, Renewable Energy Sources (RES) have become extremely attractive worldwide due to their significant ability to participate in electricity markets. The main objective of the study is to critically analyze the prospect of RES in energy and AS markets. This study concludes that still modifications in market designs and rules are required in current electricity market to integrate energy, AS and variable energy sources.

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# Optimal location and rating of wind power plants in competitive electricity market

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(Received 31 January 2017; accepted 10 August 2017; published online 23 August 2017)

A large penetration of renewable energy in a sector plays a leading role in energy generation to counter the effect of global warming on the environment. The trend in liberalized power system scenarios presents the potential of the wind power generator (WPG) to become one of the major contributors in the alternative energy production sector. Environmental conditions significantly influence the performance of these WPGs, and thus, the optimal assessment of the potential location and rating of the WPG is crucial. This paper presents a generalized model for determining the optimal location and rating of the WPG in a competitive electricity market. The multi-objective optimization problem has been formulated with an objective of maximizing the social welfare and profitability of a wind generation company by minimizing the distribution losses by optimal location and rating of WPGs in the system. To investigate the effectiveness of the proposed approach, a 39-bus New England transmission system has been modified by introducing generator and demand-side bidding. To test the validity of the proposed approach over the interconnected system, a modified 30-node radial distribution system has been considered, which is assumed to be connected with a modified 39-bus New England transmission system. The results provide a single solution for optimal location and rating of the WPG as well as a preference order based on the combination of different attributes. *Published by AIP Publishing.* [<http://dx.doi.org/10.1063/1.4999960>]

## I. INTRODUCTION

The restructuring of the power sector principally focuses on enhancing system efficiency, refining service standards, and minimizing cost by developing competitive electricity markets (CEMs). The unbundling of the power system has changed the traditional mission and mandates of utilities in several ways and has had large impacts on countries' social, economic, and environmental conditions.<sup>1</sup> Energy demands are increasing rapidly, requiring more energy resources to meet these energy demands and resulting in an exponential increase in environmental pollution and global warming if this demand is met from conventional power plants such as coal-based thermal power plants.

Renewable energy (RE) sources (RESs) are gradually being recognized as important options in CEMs. With the price of oil reaching its highest levels and non-availability of good-quality coal, combined with the desire to reduce CO<sub>2</sub> emissions, RE has become an important alternative as an energy provider.<sup>2</sup> RESs are considered one of the best options for electricity production to achieve goals such as energy independence and enhanced infrastructure reliability in the CEM, in addition to environmental emission reductions.

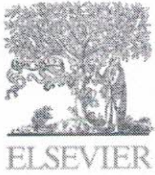
Wind power plants consist of one or more wind turbines located at different parts of a single plot of land; one turbine is referred to as a wind plant, whereas many constitute a wind

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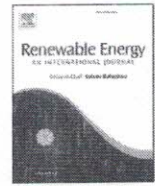




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# Renewable Energy

journal homepage: [www.elsevier.com/locate/renene](http://www.elsevier.com/locate/renene)



## Market based procurement of energy and ancillary services from Renewable Energy Sources in deregulated environment



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### ARTICLE INFO

**Article history:**  
Received 2 May 2016  
Received in revised form 4 August 2016  
Accepted 10 October 2016

**Keywords:**  
Ancillary services  
Energy market  
Energy procurement cost  
Renewable Power Producers  
Reserve market  
Reserve procurement cost

### ABSTRACT

An increasing utilization of Renewable Energy Sources (RES) in electricity generation increases the need of Ancillary Services (AS) in power system. This paper proposes a market based approach for participation of Renewable Power Producers (RPP) to clear both energy and AS in day-ahead market under disaggregated framework. This approach is based on sequential clearing of Energy Market (EM) and Ancillary Service Market (ASM) such that the cost of procuring these services is minimized and feasible solution is obtained. This optimization problem is formulated and solved using Optimal Power Flow (OPF) technique which considers all transmission constraints and power flow limits. The AS considered in the present work is limited to Reserves Market (RM) such as Ten Minute Spinning Reserve (TMSR) and Thirty Minute Replacement Reserves (TMRR) only. The ability of RPPs like Wind Power Plant (WPP) and Photo-Voltaic Plant (PVP) with conventional power producers to provide both energy and AS has been demonstrated by considering a modified 7 unit test system.

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### 1. Introduction

Unbundling of power system is one of the most significant issue in the last decade in power system area. It results in deregulation and restructuring of electrical utilities that has taken place in most of the countries around the world [1]. In present power system scenario, the former Vertical Integrated System (VIS) which was a single entity that performs all the functions related to power is now unbundled into three major components as Generation Companies (GENCOs), Transmission Companies (TRANSCOs), and Distribution Companies (DISCOs). Unbundling of power system primarily focuses on improving system efficiency, service standards and cost minimization by introducing more choices to the utility by developing competitive markets [2].

Due to massive growth in energy demand, power system equipment like generators and transmission lines are running at their full capacity. This may lead to unscheduled outages and failure of the equipment. For transmitting bulk power from generating stations to load centers, some sort of services are required that can

ensure security and reliability of the system. These services are commonly known as AS [3].

Under this scenario it is essential to procure these services in order to maintain required demand-supply balance to guarantee security and reliability of the supply. Frequency regulation, voltage regulation, operating reserves and black start services are considered as main AS in almost every country [4]. Special attention is given to reserve based AS that includes TMSR and TMRR. The former is supplied by generation that is on-line, less than fully loaded, begins responding immediately, and is fully responsive within ten minutes of a dispatch instruction by the System Operator (SO) [5] whereas later must be fully deployed in thirty or sixty minutes from on-line generation, off-line generation, and interrupted loads [6].

These services are mainly procured through the auction market mechanism. Market-clearing and settlement mechanism are the techniques that involves the determination of quantities produced and consumed, who pays, and who gets paid. Independent System Operators (ISO) typically operate various markets that includes energy and several types of AS. Merit Order based Dispatch (MOD), Sequential Dispatch (SQD) and Joint Optimization Dispatch (JOD) are three types of auction market mechanism which are used by ISO for the procurement of energy and AS in deregulated environment.

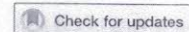
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## Power quality analysis of an AC utility-grid interfaced multilevel inverter systems

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### ABSTRACT

This paper unveils an assessment of Power Quality (PQ) and its analysis for Three-Level and Five-Level Multilevel Inverter (TL:FL-MLI) in phase control and continuous conduction mode. TLMLI and FLMLI topologies are more weighted than traditional two-level inverters due to decreased filter size and modularity. The proposed MLI systems yield increase in active power output and decrease in Total Harmonic Distortion (THD) levels. Accuracy of systems is computed by connecting a resistance-inductance and DC source load. It is envisaged that the level of THD is mitigated under variable switching control modes while injecting active power to AC utility-grid. Subsequently, the control of switching angle is achieved through Sine Pulse Width Modulation (SPWM) technique and kept in the range of 90 to 165 for optimal control. SPWM control accomplishes the task to enhance the performance of MLIs under dynamic conditions. Furthermore, the superiority of FLMLI over TLMLI is established in synthesising ripple-free and balanced waveforms with reduced harmonic levels. The efficacy and feasibility of simulations for proposed schemes is validated through a small prototype. Comprehensive comparisons with earlier attempts in literature are provided with case studies which verify the ultimate performance of proposed topologies.

### ARTICLE HISTORY

Received 31 October 2019  
Accepted 9 August 2020

### KEYWORDS


Power quality; harmonic distortion; multilevel inverters; phase controlled; utility; multi winding transformer

## 1. Introduction

A Multilevel Inverter (MLI) synthesises a sinusoidal output voltage from various connected direct current sources in various configurations. An ultimate objective of implementing MLI is to extract a staircase type sinusoidal current and voltage. In order to achieve this, Insulated Gate Bipolar Transistor (IGBT) switches are connected in series or in parallel (Rashid, 2009) at the output. However, the principle of operation of MLIs merely does not depend on two levels of voltage to generate an AC signal. Instead, various voltage levels when added to each other yields a ripple-free stepped and smooth waveform at output. Recently developed configurations of MLIs are: diode-clamp, flying-capacitors clamping type, cascaded inverters and an isolated H-bridge cell. Amongst these configurations, an isolated H-bridge converter has various H-bridge modules operating at low voltage in series configuration. Therefore in (Rodriguez et al., 2002) it is proposed that to alleviate

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## Islanding Detection Using Passive Technique

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February 6, 2018

### Abstract

The islanding is power flow between load, utility grid and distribution generation source when loss of grid is occurring. Now there is need of anti-islanding, it can be performed by using passive technique. Anti-islanding algorithm implements the scheme-of disconnection of utility grid during fault through loss of grid protection system instantaneously from DG source. The main objective of anti-islanding algorithm is to detect the loss of grid and allow the DG source to behave as Power Island which supplies the power to load only.

**Key Words :** islanding technique; passive method; under/over voltage and frequency

### 1.1. Introduction

The distribution generation (DG) sources are time-honored from the renewable source of energy (wind energy, tidal energy, thermal energy, solar energy etc.). These sources of energy are pollution free and high energy efficiency. The DG source is manufactured

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## Influence of solar photovoltaic array on operation of grid-interactive fifteen-level modular multilevel converter with emphasis on power quality



### ARTICLE INFO

#### Keywords:

Fuzzy  
Multi-level  
Solar  
Harmonics  
Dynamic voltage  
Power quality

### ABSTRACT

This paper unveils an operational impact of variable Solar Photovoltaic (SPV) array into 15-level single-stage Modular Multilevel Converter (MMC) thyristorized operated system. A MMC system is developed in which the working of three sub-system modules has been coordinated at a Point of Common Coupling (PCC). In addition, each of 15-level sub-system has been operated at a Resistance Inductance (RL) and a SPV array load. Furthermore, the investigation of DC power inversion into AC power has been elaborated by varying the switching angles of thyristors from  $100^\circ$  to  $180^\circ$  for an individual module. The operation of MMC system has been coordinated with Dynamic Voltage Restorer (DVR), where its performance has been estimated during grid faults under unity power factor conditions. Especially, the investigation on Power Quality (PQ) has been highlighted at PCC by operating with proportional integral and fuzzy logic controlled DVR. It has been verified that response with fuzzy logic DVR scheme is able to control the unbalanced conditions, under steady-state and transient conditions effectively. The effectiveness of the proposed controller is demonstrated by using standard IEEE-519/1547, which stipulates that harmonic level in utility injected current by any SPV source cannot exceed 5%. Therefore, a reduction in harmonics and DC offset is ensured satisfactorily, among all variables at PCC according to IEEE-519/1547 standard at fundamental frequency.

### 1. Introduction

Nowadays, the fossil fuel has been the main energy supplier for worldwide economy. This, however, has caused many environmental problems such as global warming and air pollution. Therefore, with regard to worldwide trend of green energy, the solar power technology [1,2] is envisaged to become one of the most promising type of energy resources [3]. At present, the number of Solar Photovoltaic (SPV) installations have seen an exponential growth [4], mainly due to the government and utility companies supporting green energy [5]. The deep integration of any renewable energy resource mainly depends on inexpensive technological improvement of global emissions and precise controlling techniques for Power Quality (PQ) [6,7].

The SPV systems with Pulse Width Modulation (PWM) controlled [8,9] inverters generate a square waveform with large harmonic content [10]. To overcome this, multilevel inverters offer sinusoidal waveform with reduced harmonic content and lower electromagnetic interference. As mentioned in references [11–14], the multilevel inverters exhibit lower switching frequency than standard PWM inverters thus, demonstrate the reduced switching losses. The modular type of multilevel converter has strong potential to replace cascaded type multilevel converter, especially in medium voltage applications [15]. Currently, intensive research is going in Modular Multilevel Converter (MMC) systems owing to their potential for medium power applications. MMC generates low harmonic at output voltage, thus eliminating filtering requirements. Moreover, it also allows avoiding interfacing transformer [16] thus, extending higher number of output levels easily. Although, the study of MMC systems is investigated with many applications, but this study has not been carried with single-stage SPV configuration. Therefore, this paper presents the analytic study on SPV grid-interactive power conversion system, coordinating with single-stage 15-level MMC system.

For a three-phase grid connected SPV system, a mathematical model based on a hybrid fuzzy-neural [17] and a 9-rule fuzzy logic control [18] has been proposed. It has been demonstrated that the fuzzy-neural control provides faster convergence speed and good dynamic operation around maximum power point. The control schemes implemented are proposed to regulate the DC bus voltage and reactive output power in rotating  $dq$ -reference frame [19–21]. The operation of a hybrid cascaded type multilevel inverter topology having three leg and H-bridge cells, has been investigated in [22]. In addition, it has been reported that maximum steps are produced in output voltage, with minimum number of required switching capacitors [23,24]. Various advantages of multilevel inverter systems which are: low power dissipation during switching, reduced harmonic distortion and electromagnetic interference; have been reported in [25]. It is their inherent ability that these inverters are capable to generate power of high quality from SPV systems and provide flexible functionality with improved PQ. The suitability of multilevel inverter for single-phase grid interaction is analyzed in [26]. The presence of several DC sources on DC side of inverter makes such inverters attractive for SPV applications.

A single-phase five-level [27], three-phase five-level [28] grid-connected SPV inverter and a multilevel H-bridge inverter [29] including battery energy storage is proposed in the literature. Total Harmonic Distortion (THD) is controlled through a digital type proportional integral current control type algorithm. This algorithm maintains the current injected into the grid sinusoidal with reduced harmonic distortion content. Additionally, the THD in voltage for a multilevel H-bridge inverter which includes battery as energy storage source, is found to be less than 6%.

<http://dx.doi.org/10.1016/j.rser.2017.03.092>

Received 26 July 2016; Received in revised form 12 February 2017; Accepted 20 March 2017  
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# A Hybrid Model of Grid Connected Sola Photovoltaic (PV) Cell with Partial Shading

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## Abstract

Solar Photovoltaic (PV)-Hydro Diesel cells are being used in electric power sector from a very long time. These solar PV cells have found their wide utilisation in commercial aspects. With the reduction of oil based fossil fuel resources, the various advancements taking place in solar PV technology have further amounted to this important cause. A major challenge in this field is to track the point of highest output power from the solar PV cells. In order to achieve this, various Maximum Power Point Tracking (MPPT) techniques have been studied and analysed in the literature. Out of all, the two techniques Perturb and Observe (P&O) and Incremental Conductance (IC) are the basic MPPT techniques which are simple to implement and analyse. This paper endeavours a novel adaptive new hybrid technique algorithm which is based on inference system for MPPT technique. The proposed hybrid under partial shading solar PV model with MPPT technique performs quite better when compared with other techniques in terms of transient state response.

**Keywords:** Double-diode, Maximum Power, Perturb and Observe, Photovoltaic, Single-diode

## 1. Introduction

Today, in India, the major share of electric power is harnessed from the coal based or non-renewable energy source. It will continue to be a major source of pollution and other environmental degradation. Finding the sustainable alternative is becoming increasingly urgent due to these problems and the dwindling supply of coal based resources. After hydro and wind type of electric power, Solar Photovoltaic (PV) is third most important renewable energy sources in terms of globally installed capacity. In Solar PV system, solar panels are used for converting solar energy into electrical energy. These solar panels consist of PV cells (also sometimes called as solar cells).

The lack of adequate transmission capacity is one of major impediment in implementing renewable energy sources into transmission utility grid<sup>1</sup>. It also presented a novel control for a grid-connected solar PV farm which can improve transient-state stability limit. It also improved power transfer capability of transmission line into utility grid. An algorithm for a new MPPT technique, which can effectively, improves the performance of a solar PV system<sup>2</sup>.

The proposed algorithm has been explained in two sections, one is set-point calculation whereas another is fine-tuning. The calculation of set-point is based on method of short-circuit current, in which approximation of maximum power is done. In second section, an exact amount of maximum solar PV power is tracked by fine-tuning. This process is based on basic Perturbation & Observation (P&O) MPPT technique. In <sup>3</sup> it is suggested that MPPT techniques of analog nature, which provides faster response over MPPT techniques of digital type. Due to the fact that bandwidth of the analog type loop is higher, thus, most analog MPPT techniques require analog type multipliers. These multipliers are expensive in cost and consume more power. Hence, different low-cost microcontrollers which consume low-power, with built-in hardware digital multipliers have been manufactured by Texas Instruments and Microchip. In <sup>4</sup> a voltage-based and current-based MPPT technique is presented and discussed. It has been found that both approaches are efficient and simple. These MPPT approaches present poor active power tracking efficiencies particularly at variable insulation levels. In <sup>5</sup> a new methodology is introduced. The analysis and derivation of the non-linear I-V curves of

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# Comparative Power Quality Analysis of Different Discontinuous Phase Control Grid-interactive Converter Systems

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## ABSTRACT

Employing multilevel inverters is a novel kind of converter used to reduce harmonic content of output voltage and current and Electromagnetic Interference (EMI) in high power applications. The conventional line commutated DC-AC inverters have square-shaped line current which contains higher-order harmonics. The line current with the high harmonic contents generates EMI and moreover it causes more heating of the core of distribution/power transformers. In the present work, a different line commutated inverter topology has been proposed and analyzed with discontinues phase control switching technique which improves the wave shape and hence reduces the Total Harmonic Distortion (THD) of the line current in a grid tie line commutated inverter. Proposed inverter circuit is supplied with a DC source at various levels which can be implemented by research engineers working in PV fed inverter and grid interactive systems.

**Keywords:** Power quality, harmonic distortion, multilevel inverter, grid, DC source

## 1. INTRODUCTION

A Multilevel converter is a power electronic system that synthesizes a sinusoidal AC output voltage from several DC sources. The basic aim of using MLI is to generate a staircase type sinusoidal voltage and current at the output by using thyristor or inverter switches in series [1]. The concept of MLIs does not depend on just two levels of voltage to create an AC signal. Instead, several voltage levels are added with each other in order to create a smooth stepped waveform at the output. The commonly used converter systems can be classified into various categories: flying capacitors, diode-clamped, and isolated H-bridge cell. Among them, an isolated H-bridge converter has various H-bridge modules at low voltage which are connected in series. Each converter module has its own independent source. Therefore, in [2], it is mentioned that to remove the shortcomings of an isolated H-bridge type converter, an isolated transformer is proposed which can be operated on single DC voltage source. Few high power applications are reported in [3] in which these converter systems have found its use are large motor drives, flexible AC transmission systems, and renewable energy sources. Additionally, this technology has been widely used for power quality improvements and reactive power compensation.

An important application of solar photovoltaic based power generation is reported in [4] in which it feeds the generated DC power into utility grid, after its conversion into AC power. To achieve this, the Pulse Width Modulation (PWM) inverters have been implemented for gate commutated devices. However, apart from higher switching losses, the power handling capability and reliability of these semiconductor devices are quite low in comparison to thyristors, as mentioned in [5]. Furthermore, the switching angles play an important role in order that the output voltage and current has low harmonic distortion. Various

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