

**ANALYSIS, DESIGN AND CONTROL OF
RENEWABLE ENERGY BASED AUTONOMOUS
DISTRIBUTED GENERATING SYSTEMS**

by

PUNEET KUMAR GOEL
Department of Electrical Engineering

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CERTIFICATE

This is to certify that the thesis entitled, “**ANALYSIS, DESIGN AND CONTROL OF RENEWABLE ENERGY BASED AUTONOMOUS DISTRIBUTED GENERATING SYSTEMS,**” being submitted by Mr. Puneet Kumar Goel for the award of the degree of Doctor of Philosophy is a record of bona fide research work carried out by him in the Department of Electrical Engineering of the Indian Institute of Technology, Delhi.

Mr. Puneet Kumar Goel has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis, which to our knowledge has reached the requisite standard. The results obtained here in have not been submitted to any other University or Institute for the award of any degree.

(Prof. S. S. Murthy)

**Professor
Department of Electrical Engineering
Indian Institute of Technology Delhi
New Delhi-110016, INDIA
Email: ssmurthy@ee.iitd.ac.in**

(Prof. Bhim Singh)

**Professor
Department of Electrical Engineering
Indian Institute of Technology Delhi
New Delhi-110016, INDIA
Email: bsingh@ee.iitd.ac.in**

Dated:

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(Puneet K. Goel)

IIT, New Delhi

ABSTRACT

Renewable energy resources have attracted world-wide attention due to soaring prices and fast depletion of fossil fuels and climate change concerns. Renewable energy resources are considered important in improving the security of energy supplies by decreasing the dependency on fossil fuels and in reducing the emissions of greenhouse gases (GHG). From Copenhagen summit (2009), it is clear that the survival of our planet, renewable energy and energy efficiency must be in centre stage and technology development to exploit such resources should get priority. This thesis is in line with such global concerns. Renewable energy resources broadly comprising wind, solar, small-hydro, geothermal, bio-fuels etc. are both natural and inexhaustible. Amongst these renewable energy resources, wind, solar, small hydro and bio-energy are in the forefront with different stages of maturity for field deployment. The growth of wind and solar photovoltaic (PV) generation systems has exceeded the most optimistic estimates worldwide. Although the potential for small hydroelectric systems depends on the availability of suitable water flow, where the resource exists it can provide cheap, clean, reliable electricity.

Each of the renewable energy resources technologies has its own drawbacks. For example, wind and solar energy resources are highly dependent on climate. Moreover, due to intermittent nature many of the renewable energy resources require power electronic interfaces and energy storage devices such as battery energy storage systems (BESSs). Further different renewable energy resources can complement each other to some extent. Therefore, multi-source hybrid renewable energy resources have great potential to improve quality and reliability of power supply to customers.

There are a large number of human habitats in the world, where grid-fed electrification is often unviable or uneconomical. Such habitats require autonomous systems to supply power of desired power quality to variety of local loads such as, balanced/unbalanced linear loads, balanced/unbalanced non-linear loads and dynamic loads. Typical uses of electricity in such areas are lighting, heating, motion (fans, pumps), entertainment, and ICT (Information and Communication Technology) applications.

In this thesis, the investigations are made on various configurations of the autonomous distributed generating systems based on renewable energy resources along with BESS. The various generating systems considered are wind energy conversion systems (WECSs), solar photovoltaic (PV) systems, wind-small hydro hybrid systems and wind-solar PV hybrid systems. Typical power rating of such systems may be in the range of 20-100kW. The general outlining philosophy for the proposed systems is centered on back to back ac-dc-ac converter with a battery in the dc bus for load leveling.

Different configurations of autonomous variable speed WECS, using doubly fed induction generator (DFIG), permanent magnet synchronous generator (PMSG), squirrel cage induction generator (SCIG) and their control strategies are proposed to address the issues of voltage and frequency control (VFC) and achieve maximum power tracking (MPT) with change in wind speed. Amongst renewable energy resources, small-hydro and wind energy have ability to complement each other. Thus the investigations are carried on new configurations for autonomous wind-hydro hybrid systems. The proposed systems use DFIG/PMSG/SCIG for generation from wind energy and SCIG/PMSG for small hydro generation. Amongst renewable energy resources, solar PV systems are expected to play an important role as a clean electricity source in meeting future

electricity demands. The issues of maximum power point tracking (MPPT) with change in solar irradiance and VFC are addressed for autonomous solar PV systems. Different topologies using star-delta, zigzag and T-connected transformers have been proposed on the load side of the system of these solar PV systems. Also the issues of design, modeling and VFC are addressed for autonomous wind-solar PV hybrid systems.

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