INVESTIGATIONS ON CONTROL ALGORITHMS FOR SOLAR PHOTOVOLTAIC GRID INTERFACED SYSTEMS

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by

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CERTIFICATE

It is certified that the thesis entitled "**Investigations on Control Algorithms for Solar Photovoltaic Grid Interfaced Systems**," being submitted by **Mr. Amresh Kumar Singh** for award of the degree of **Doctor of Philosophy** in the Department of Electrical Engineering, Indian Institute of Technology Delhi, is a record of the student work carried out by him under my supervision and guidance. The matter embodied in this thesis has not been submitted for award of any other degree or diploma.

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Amresh Kumar Singh

ABSTRACT

This research work aims the design, control and implementation of different three phase configurations of solar power generating system for interfacing the solar photovoltaic (PV) energy into the three phase grid with an improved power quality. Modelling, simulation and performance evaluation of three phase solar energy generating systems, have been carried out in MATLAB/Simulink. The laboratory prototypes of all these configurations, are developed to validate the simulation results.

This work presents various VSC based system configurations and novel control algorithms of SPGSs (Solar PV Power Generation Systems) interfaced to the three-phase grid for both single stage and double stage system depending upon requirements. Their simple and effective control approaches have shown their performance potential under ideal and non-ideal grid conditions as well as nominal and worst ambience conditions.

Moreover, when solar power is not available, normally the SPGS configuration is switched off to reduce the losses. This leads poor utilization of power converters, which are used in grid interfaced PV system. Therefore, in order to improve the utilization of solar PV systems, multi-objective grid interfaced SPGSs in different configurations, are proposed in this work. These solar energy generating systems include traditional PV inverter configurations with improved MPPT (Maximum Power Point Tracking) scheme as well as the multitasking PV configurations. At the same time, these multi-tasking configurations help in enhancement of power quality of the distribution system in abnormal grid conditions such as voltage distortion, voltage imbalance and voltage variation at PCC (Point Of Common Coupling) with the basic characteristic of PV power fed into distribution network. Moreover, in the absence of solar energy, this multitasking PV inverter works to enhance the power quality of distribution system without any additional device like DSTATCOM (Distribution Static Compensator). Hence, in

this way, by utilizing the power converter up to its extreme level, the payback time of the grid interfaced SPGSs, is reduced. The performance improvements are studied in terms of minimization of losses and ripple currents. Simple, novel and robust control approaches are proposed for all these grid integrated SPGSs. Additionally, the performance evaluation for all the system configurations, has been analyzed under ideal and non-ideal grid conditions. The behavior of SPGSs, are also examined under standard and worst ambience conditions. This work gives a good exposure to design, development and implementation of various simple and efficient control approaches for grid interfaced PV system and multipurpose SPGSs.

सार

इस शोध कार्य में सौर ऊर्जा उत्पन्न करने वाली प्रणाली के डिफरेंट 3-फेस कॉन्फ़िगरेशंस के डिजाइन, नियंत्रण और कार्यान्वयन का उद्देश्य, सौर फोटोवोल्टिक (पीवी) ऊर्जा को 3-फेस ग्रिड में एक बेहतर बिजली की गुणवत्ता के साथ इंटरफेस करने के लिए है। 3-फेस सौर ऊर्जा उत्पादन प्रणालियों के मॉडलिंग, सिमुलेशन और प्रदर्शन मूल्यांकन, MATLAB / Simulink में किए गए हैं। इन सभी कॉन्फ़िगरेशंस के प्रयोगशाला प्रोटोटाइप, सिमुलेशन परिणामों को प्रमाणित करने के लिए विकसित किए गए हैं।

यह कार्य विभिन्न वीएससी आधारित सिस्टम कॉन्फ़िगरेशंस और एसपीजीएस (सौर पीवी पावर जनरेशन सिस्टम) के नवीन नियंत्रण एल्गोरिदम प्रस्तुत करता है जो आवश्यकताओं के आधार पर एकल चरण और डबल चरण प्रणाली दोनों के लिए 3-फेस ग्रिड में इंटरफेस किया जाता है। उनके सरल और प्रभावी नियंत्रण दृष्टिकोण ने आदर्श प्रदर्शन और गैर-आदर्श ग्रिड स्थितियों के साथ-साथ नाममात्र और सबसे खराब वातावरण स्थितियों के तहत अपनी प्रदर्शन क्षमता दिखायी है।

इसके अलावा, जब सौर ऊर्जा उपलब्ध नहीं होती है, तो आम तौर पर ऊर्जा खपत को कम करने के लिए एसपीजीएस कॉन्फ़िगरेशन बंद कर दिया जाता है। इससे पावर कन्वर्टर्स का खराब उपयोग होता है, जिसका उपयोग ग्रिड इंटरफेस्ड पीवी सिस्टम में किया जाता है। इसलिए, सौर पीवी सिस्टम के उपयोग में सुधार करने के लिए, विभिन्न कार्यप्रणाली में बहु-उद्देश्य ग्रिड

इंटरफेस्ड एसपीजीएस, इस काम में प्रस्तावित हैं। इन सौर ऊर्जा उत्पन्न प्रणालियों में उन्नत एमपीवीटी (मैक्सिमम पावर प्वाइंट ट्रैकिंग) विधि के साथ-साथ मल्टीटास्किंग पीवी कॉन्फ़िगरेशन के साथ पारंपरिक पीवी इन्वर्टर कॉन्फ़िगरेशन शामिल हैं। साथ ही, इन मल्टी-टास्किंग कॉन्फ़िगरेशन पीवी पावर फेड की मूल विशेषता के साथ पीसीसी (पॉइंट ऑफ़ कमान कपलिंग) पर वोल्टेज डिस्टॉरशन, वोल्टेज इम्बैलेंस और वोल्टेज वेरिएशन जैसे असामान्य ग्रिड स्थितियों में वितरण प्रणाली की बिजली की गुणवत्ता में वृद्धि में मदद करते हैं। इसके अलावा, सौर ऊर्जा की अनुपस्थिति में, यह मल्टीटास्किंग पीवी इन्वर्टर किसी भी अतिरिक्त डिवाइस जैसे डीएसटीएटीकॉम (वितरण स्टेटिक कम्पेन्सेटर) के बिना वितरण प्रणाली की बिजली की गुणवत्ता को बढ़ाने के लिए काम करता है। इसलिए, इस तरह, पावर कनवर्टर को अपने चरम स्तर तक उपयोग करके, ग्रिड इंटरफेस एसपीजीएस का भुगतान समय कम हो जाता है। हानि और रिप्पल धाराओं को कम करने के संदर्भ में प्रदर्शन सुधार का अध्ययन किया जाता है। इन सभी ग्रिड एकीकृत एसपीजीएस के लिए सरल, नवीन और प्रभावी नियंत्रण दृष्टिकोण प्रस्तावित किए गए हैं। इसके अतिरिक्त, सभी सिस्टम कॉन्फ़िगरेशंस के लिए प्रदर्शन मूल्यांकन, आदर्श और गैर-आदर्श ग्रिड स्थितियों के तहत विश्लेषण किया गया है। एसपीजीएस के व्यवहार की मानक और सबसे खराब स्थितियों के तहत भी जांच की जाती है। यह काम ग्रिड इंटरफेस्ड पीवी सिस्टम और बहुउद्देश्यीय एसपीजीएस के लिए विभिन्न सरल और कुशल नियंत्रण

दृष्टिकोणों के डिजाइन, विकास और कार्यान्वयन के लिए एक अच्छा अनावरण प्रदान करता है।

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PV	Photovoltaic
SPGSs	Solar PV Power Generation Systems
PCC	Point of Common Coupling
DSTATCOM	Distribution Static Compensator
VSI	Voltage Source Inverter
FS	Fast Sparse
CIM	Correntropy Induced Metric
AS	Adaptive Sparse
FZA	Fast Zero Adaptive
RZA	Re-weighted Zero Norms
MPPT	Maximum Power Point Tracking
P&O	Perturb & Observe
LMF	Least Mean Fourth
NLMS	Normalized Least Mean Fourth
SRFT	Synchronous Reference Frame Theory
PQ	Power Quality
OCV	Open Circuit Voltage
SCC	Short Circuit Current
ESC	Extreme Seeking Control Method
OCC	One Cycle Control