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Master Program of Renewable Energy and Sustainability

Investigate the Influence of the Penetration level of PV Distributed Generation and Energy Storage Integration on the Medium Voltage Distribution Network

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Palestine Polytechnic University

Deanship of Graduate Studies and Scientific Research

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Thesis submitted in partial fulfillment of requirements of the degree

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ABSTRACT

Electrical Power System is centralized energy frames, power flows from generation plant to distribution network through transmission lines of the grid, which means that the conventional system has a unidirectional power flow. The increasing of electrical energy consumption and the immediate need of electricity today leads to enhance and develop the electrical power system. Using of renewable energy systems, especially solar energy is one of the solutions to produce sustainable and environmentally friendly electrical energy systems. This study supports the photovoltaic (PV) system as a renewable source, but the intermittency of the solar energy and variation of weather conditions, besides of high impact of the high penetration of PV systems are stands as a main drawback of the grid connected PV system. However, in the field of operation and planning of electrical power systems point of view, using an Energy Storage System (ESS) integrated with grid connected PV systems are filling the gap of the grid-tied PV system by reduce the PV impact, maximizing the penetration level of DG and enhancing the grid stability through getting a backup source of the system.

The objective of this thesis is investigating the effects and performance of integrating grid-tied PV system with the conventional power system through the conduction of a real case study 230 kWp PV power plant on the Palestine Polytechnic University (PPU) distribution medium voltage feeder and determine the penetration level of the PV system on the PPU feeder. Moreover, battery energy storage system (BESS) proposed to be integrated with the grid-tied PV system due to maximize the allowable PV Penetration and eliminate the grid connected PV system impact issues to the grid.

However, a modelling of the case study PPU feeder and the PV station and the proposed BESS was conducted using Electrical Transient Analyzer Power (ETAP) software where the daily load profile built to be inserted to the system model in the form of four scenarios: i) electrical network alone, ii) electrical grid with PV system integration, iii) electrical grid with BESS and iv) electrical grid with PV and BESS integration, the aim of studying these cases is to improve the strengthen power networks and to verify the results with the IEEE standard. In the results of this thesis, it is shown that the PV hosting capacity of a distribution power grid can be increased using the investigated methods, in addition to that the technical impact of the PV power plant minimized especially of the PF, voltage drop and power issues.

دراسة تأثير مستوى إسهام الإنتاج الموزع الكهروضوئي وتكامله مع أنظمة تخزين الطاقة على شبكة توزيع الجهد المتوسط

ملخص:

نظام الطاقة الكهربائية بشكلٍ عام، عبارة عن نظام مركزي في إنتاج الطاقة الكهربائية؛ حيث أن الطاقة المنتَجة تتدفق من محطة التوليد إلى المستهلكين عن طريق نظامي النقل والتوزيع الخاصيّن بالشبكة، أي أنه نظام أحادي الإتجاه (من المنتج إلى المتسهلك)، ويسمى هذا النظام بالنظام التقليدي. مع زيادة الإستهلاك والحاجة إلى الطاقة في كافة مناحي الحياة في يومنا الحاضر، كان لا بدّ من تطوير وتعزيز نظام الطاقة الكهربائية التقليدي و المساهمة في خلق نظامٍ كهربائي قادرٌ على تلبية الحاجات الكهربائية المختلفة حيث تمثلت هذه المساهمة في استخدام أنظمة الطاقة المتجددة على اختلاف أنواعها، وأهمها الطاقة الشمسية الكهروضوئية لأنها وسابقاتها تعد من المصادر المستدامة والصديقة للبيئة حيث أنها تعمل على تخفيف الآثار البيئية الناجمة عن الطرق التقليدية في توليد الطاقة الكهربائية. تقوم هذه الدراسة على اعتماد نظام الطاقة الشمسية كمصدر الطاقة المتجدد الخاص بالشبكة المستخدمة، ولكن، نتيجة للتغيرات الجوية اللحظية المتكررة والتي تؤثر على إنتاجية الخلايا من الطاقة، إلى جانب نسبة الإسهام العالي من الطاقة الكهربائية الناتجة عن محطات الطاقة الكهروضوئية الموزعة، كلتاهما أوجدتا عيوبًا ذمّت النظام وكوّنتا فجوةً فيه، ومع ذلك فإن هناك حلًا متاحًا يتمثل في استخدام نظامٍ آخر مرافق لنظام الطاقة الشمسية يكون في ذات الوقت قادرًا على تغطية الفجوة الناجمة، هذا النظام هو (نظام بطاريات تخزين الطاقة- "Battery Energy Storage System" BESS)؛ تتكامل البطاريات مع الخلايا من أجل تقليل نسب الإسهام من محطات التوليد الكهروضوئية، وتعزز استقرار الشبكة في حالاتٍ تكون فيها الخلايا غير قادرة على تزويد الطاقة لأي سبب كان، كما وأنها تمثل مصدرًا إحتياطيًا للطاقة في النظام.

إن الهدف الأساسي من هذه الأطروحة يتمثلُ في دراسة تأثيرات وأداء النظام الكهروضوئي على صعدٍ عدة، كأن يتم ربطها مع شبكة الطاقة، كما في الحالة الحقيقية المستخدمة في الدراسة، حيث بلغت سعةُ نظام الطاقة الشمسية المرتبط بنظام الشبكة الجهد المتوسط خاصةً بجامعة بوليتكنك فلسطين 230 KWp ، يتم فيها تحديد مستوى الإسهام من النظام الكهروضوئي على الشبكة. بعد ذلك يتم دمج نظام تخزين الطاقة (البطاريات) مع نظام الخلايا المرتبط بالشبكة لمعرفة الحد الأقصى المسموح به للإسهام، ولإزالة التأثيرات السلبية الناجمة عن تركيب الخلايا وحيدةً كـ مولدات طاقة متجددة مستفردةً على الشبكة.

تقوم الدراسة على عمل نمذجة أو محاكاة لمغذيات جامعة بوليتكنك فلسطين ونظام الخلايا المرتبط بها، ونظام تخزين الطاقة المقترح أيضًا، ليتم دراسة حالتها، وذلك باستخدام برنامج ETAP (Electrical Transient Analyzer Power)، حيث تم خلال العمل تحديد الحمل اليومي وبناؤه بما يناسب البرنامج وادخاله على الشبكة المصممةٍ فيه؛ تقوم الدراسة على أربعِ سيناريوهات مختلفة: أ) دراسة خصائص الشبكة وحدها، ب) تكاملٌ ما بين الشبكة ونظام الخلايا الشمسية، ج) دراسة الشبكة مع نظام التخزين كنظام مركب، د) دراسة الشبكة مدمجة مع كلٍ من نظامي الطاقة الشمسية والتخزين؛ تكمن الأهداف الرئيسة لدراسة هذه الحالات في تحسين وتقوية خصائص الشبكة الكهربائية، ومقارنة النتائج مع المعايير العالمية المعتمدة من قِبل IEEE؛ من الجدير بالذكر أن النتائج التي تم الحصول عليها في هذه الأطروحة تشير إلى أنه يمكن زيادة سعة الإسهام الكهروضوئي على شبكات التوزيع من خلال الطريقة التي تم توضيحها، وعلى نفس النهج، تشير إلى أنه يمكن تقليل التأثيرات التقنية السلبية الناجمة على الشبكة نتيجة استخدام الخلايا الشمسية وحدها، أهم هذه التأثيرات تتمحور حول تغيراتٍ في قيم الجهد إلى قيم أقل مما يُسمح به، أو قضايا تتعلق بمعامل القدرة (PF).

DECLARATION

I declare that the Master Thesis entitled "**Investigate the influence of the Penetration level of PV Distributed Generation and Energy Storage Integration on the Medium Voltage Distribution Network**" is my own original work, and herby certify that unless stated, all work contained within this thesis is my own independent research and has not been submitted for the award of any other degree at any institution, except where due acknowledgement is made in the text.

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Date: 6/2/2020.

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DEDICATION

Say: Truly, my prayer and my service of sacrifice, my life and my death, are all for Allah, the Cherisher of the Worlds [162, Al-An'am]

This thesis is dedicated to:

The sake of Allah, my Creator and my Master,

My great teacher and messenger, Mohammed (PBUH), who taught us the purpose of life,

My great parents, who never stop giving of themselves in countless ways,

My beloved brothers and sisters; for their support,

My lecturers for help me until the end,

My friends; whom give me Positive sentiment and support,

Palestine Polytechnic University and Al-Quds University, my second magnificent home;

My supervisors Dr. Maher Maghalseh and Dr. Nassim Iqteit,

To all the people in my life who touch my heart,

To our great Palestine

I dedicate this research to all who made this work is possible

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