Budapest University of Technology and Economics
Faculty of Electrical Engineering and Informatics
Department of Electric Power Engineering

Sayed Mohamed Said Mohamed

Improving Power System Reliability and Stability by Cooperation of Distributed Generation and Energy Storage System

PhD Dissertation Booklet

SUPERVISOR

Dr. Bálint Hartmann, PhD

Budapest, 2020

1. Introduction

Nowadays, power system stability and reliability are considered as the most pressing issues worthy of studying and analyzing in modern electric power systems. The use of renewable energy sources (RESs) is one of the noteworthy strategies to reduce the dependence on fossil fuels and consequently mitigate the environmental pollution impacts. The most popular types of these RESs are wind power, solar photovoltaic (PV), solar thermal systems, biomass, and various forms of hydraulic power. Several problems have been addressed by installing wind power generation (WPG) and solar PV generation systems to the electric power system. Wind speed always changes by increasing/decreasing around the average wind speed value, causing variable output power of WPG. Furthermore, due to the intermittent nature of the solar irradiance, the PV output power will be affected. Consequently, power system stability and reliability will be affected by these conditions accordingly.

Energy storage systems (ESSs) have an important role to aid in solving the above-mentioned problems and in mitigating the fluctuating nature due to the increase in the penetration level of RESs in the electrical power system. The main contribution of employing ESSs in electrical power networks is to mitigate the active/reactive power transfer from/to the utility power grid during normal conditions and when it is subject to disturbances. Among various ESSs, the superconducting magnetic energy storage (SMES) systems have proven themselves as an effective solution. In addition, SMES systems have a short time delay during charging/discharging processes, high efficiency, and long lifetime. Fuzzy logic control (FLC) is considered one of the advanced and robust controllers which can control the energy transfer between the power system and energy storage system.

The main goal of this research work is to enhance the performance of power system stability and reliability of the electric power system which included distributed generation (DG) systems. PV and WPG are considered from the most growth RESs in worldwide. The intermittent nature of wind speed and solar irradiance, as well as the abnormal conditions due to random load changes, are the critical issues on the stability and reliability of the electrical power system. Moreover, a developed SMES with the FLC method is proposed to enhance the stability and reliability of the electrical power system in the presence of RESs by fast charging/discharging energy between the power system and SMES.

2. Research Objectives

As presented in the literature, several research works have been accomplished to enhance the stability and reliability of the power systems by cooperating SMES with RESs; nevertheless, these attempts have either drawbacks or deficiencies that are summarized in the following:

- Existing methods studied the behavior of SMES with WPG to mitigate the power and voltage fluctuations during wind speed transients. However, the mitigation of WPG output power during high wind gusts and taking into consideration the load power variations have not addressed. There are several attempts in the literature to provide solutions for solving voltage and frequency instability issues in the distribution systems. Nevertheless, both the SoC of SMES and high wind speed transient impacts are not considered especially in unbalanced distribution networks.
- Proposals exist to use SMES in improving the reliability of the islanded MGs integrated with WPG/PV. But the impact of WPG/PV station insertion during operation time and the sudden rejection of the large electric loads are not included in the designing of the SMES control.
- Existing approaches proposed the application of SMES in the MG equipped with a PV generation system to control and minimize the tie-line power flow between the MG and the utility grid. However, these approaches have not considered the optimal value of active and reactive SMES output power to reduce the thermal stress due to the overcharging and deep discharging states of SMES, which may cause its failures and shortened lifetime. Additionally, proposals exist to utilize SMES with a hybrid WPG/PV system to mitigate power and voltage fluctuations. Although, a high irradiance variation, wind gust events, and the random variation of load demand have not included together in the proposed control.
- Existing methods used to investigate the cooperation between SMES (as energy storage) and EVs (as a controllable load) did not consider the coordination control strategy between SMES and EV for reducing the distribution system power loss, minimizing voltage fluctuation at peak load period, and avoiding congestion in the distribution network.
- The coordination between SMES and protection devices to improve the reliability of a real power system is based on a simplified SMES model in some of the research works.

Most of the research work has not considered either the complete SMES model nor the appropriate control method.

Motivated by the aforementioned insufficiency, this dissertation presents efficient control methods for the SMES to deal with these drawbacks. By applying these methods, the fluctuating of active/reactive power and voltage of the power system can be significantly mitigated, and the system total power loss is clearly reduced. The main goal of this work is to improve the stability and reliability of the power system by cooperating SMES and RESs. The research objectives, which will be accomplished in this work to face the challenges listed above and enhancing the stability and reliability of the power system are in the following.

2.1 Mitigation Voltage/Power Fluctuation and Stability Improvement

To mitigate both voltage and power fluctuations of a grid-connected WPG during the wind gust and load power variations, a developed FLC-SMES is proposed. The proposed control is designed in order to enable SMES to rapidly charge/discharge both active and reactive powers to meet the power and voltage fluctuations. In addition, the voltage and frequency stability issues are enhanced by employing the SMES system based on the FLC method. This proposed method for SMES can improve the performance of three-phase balanced and unbalanced distribution systems considering the high wind speed variation and large unbalanced loading conditions.

2.2 Robust SMES Control for Improving MG Reliability

To enhance the reliability of islanding MGs including WPG/PV units, a robust FLC method is proposed for SMES. This proposed method can regulate the system frequency and PCC voltage to the acceptable value during both load rejection and WPG/PV insertion scenarios. Moreover, the reliability of both the grid-connected PV-MG system and the hybrid PV-wind grid-connected system is improved with employing the proposed FLC-SMES. Therefore, the tie-line power between MG and the utility grid and the total system power losses are significantly minimized.

2.3 Cooperation between SMES and EVs

To improve the distribution networks' performance in the presence of both EVs and SMES, an efficient coordinated control strategy is proposed between SMES and EVs. This coordination control is based on the FLC method which utilizes for SMES and EVs via a common electricity price control signal. This method can effectively minimize the total power loss, reduce the active and reactive required grid power, keep the PCC voltage at acceptable standard value.

2.4 Coordination of SMES with Digital Protection System.

To operate with high reliability and more secure for low inertia power systems, a proposed SMES based FLC method is coordinated with the digital protection system. This coordination strategy can effectively improve the frequency of low inertia power systems and maintain dynamic stability and security in admissible limits due to different load and RESs disturbances.

3. Thesis Outline

This thesis is arranged as follows:

Chapter 1: presents the definition and description of stability and reliability of power system, comprehensive background and application about ESSs especially SMES, research goals, and structure of the thesis.

Chapter 2: describes the detailed modeling of SCIG based wind turbine, construction of solar PV generation system, complete SMES configuration, and the description of FLC.

Chapter 3: introduces a proposed FLC method to mitigate the power and voltage fluctuation of the grid-connected distribution network due to extreme wind speed variation. Additionally, improving the small disturbance voltage and frequency stabilities for both balanced and unbalanced distribution systems.

Chapter 4: proposes a robust FLC for SMES to enhance the reliability of the islanded MG equipped with the WPG/PV system during the insertion of the WPG/PV unit and sudden load rejection.

Chapter 5: offers two proposed methods for minimizing the tie-line power flow between the MG with PV and the utility grid in the presence of SMES. In addition, robust control of SMES is proposed to mitigate power and voltage fluctuations of a hybrid PV-wind power generation system integrated with the utility grid during high irradiance variation, wind gust events, and uneven load power demand.

Chapter 6: provides a coordination strategy between SMES and electric vehicles (EVs) in the charging/discharging process including EV's charging price to improve the characteristics of EVs charging/discharging moreover, regulate line active/reactive power to achieve a load balance operation.

Chapter 7: proposes a coordination control strategy between SMES, load frequency control (LFC), and digital frequency relay (DFR) to improve the frequency stability.

Chapter 8: concludes the contributions of the thesis. The potential future direction of research is also offered in this chapter.

To provide a complete picture and help to understand the contents and the distribution of contributions between the different chapters, Figure 1 describes the complete workflow in the dissertation, which is divided into four parts, namely, Part I, Part II, Part III, and Part IV.

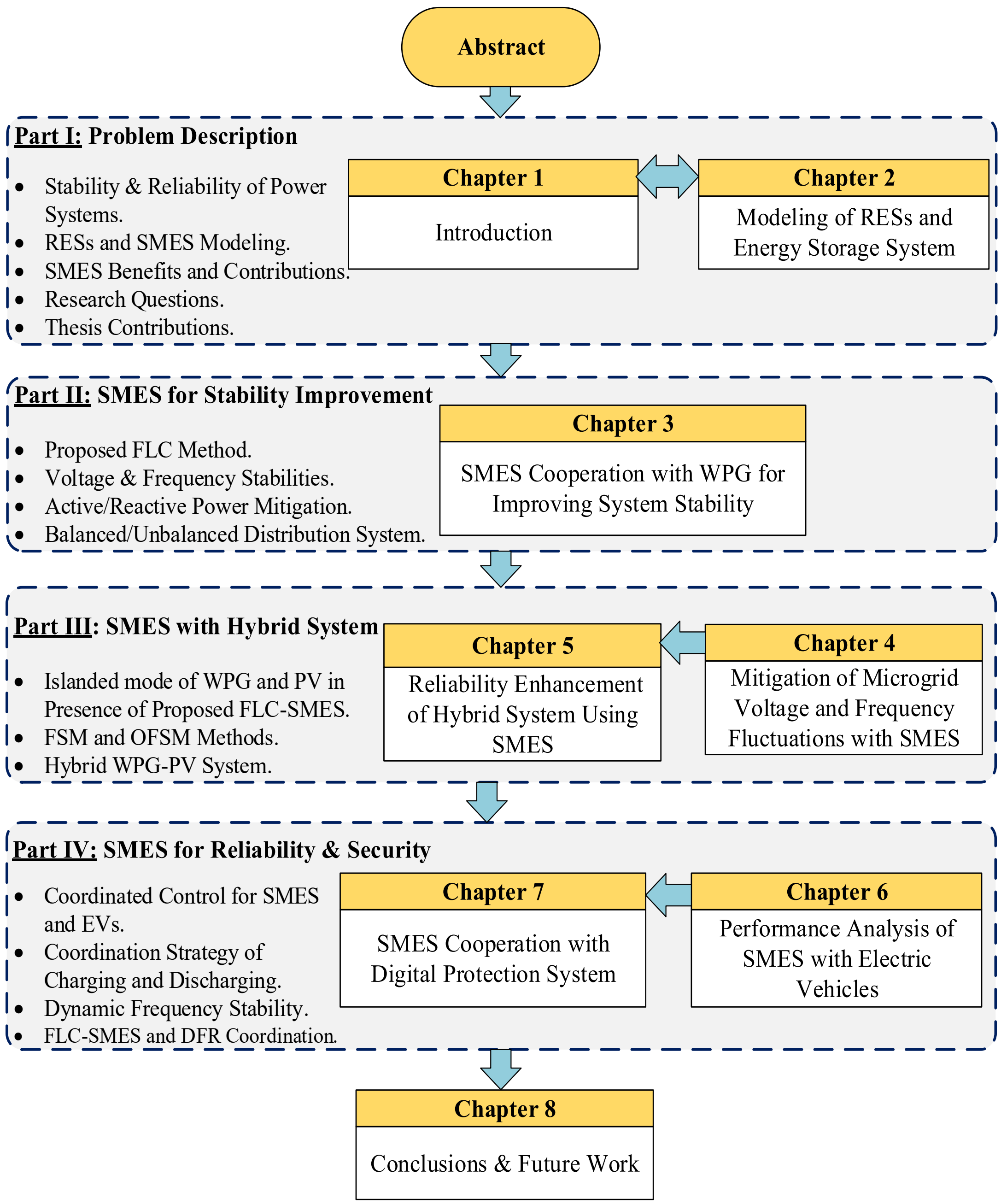

Figure 1 Organization of the dissertation.

4. Theses

4.1 Thesis 1

“A novel control strategy of SMES has been proposed to mitigate the power and voltage fluctuations due to WPG transients and random load variations. The proposed FLC method of SMES is robust, as it has successfully controlled the voltage at PCC, active and reactive powers during normal wind speeds and for different scenarios of wind gusts. Furthermore, the impact of the proposed control in enhancing the voltage profile for three-phase balanced/unbalanced radial distribution systems has been tested. Moreover, load variations in the presence of intermittent WPG are taken into consideration in the design process of the SMES controller. The obtained results proved the best performance of SMES in the combination with WPG to mitigate the voltage and power fluctuations due to wind speed variations in addition to the load demand variations. Therefore, the superiority of the FLC method that enables SMES to operate with fast response in all modes of operation has been demonstrated.”

The related work is presented in Chapter 3 of the dissertation and has been published in [J8], [J9], and [C10].

In this thesis, a developed control approach of the SMES system is proposed for controlling it's active and reactive powers to regulate voltage and power interchange as well as mitigating voltage and frequency stability problems associated with the fluctuating nature of WPG and the random load changes. The proposed system is validated using a grid-connected and the IEEE 33-bus distribution systems. Both WPG and SMES are connected at the PCC. FLC is designed in order to enable SMES to rapidly charge/discharge both active and reactive powers to compensate the fluctuation of voltage, frequency, line real power, and line reactive power at PCC. With the proposed FLC method, SMES has success to rapidly discharge and charge the stored energy during high wind fluctuation and randomly load variation. This, in turn, helped in regulating the PCC voltage to the acceptable standard limits. It also success to mitigate the line active and reactive powers transfer between WPG and PCC during the extreme variations of wind speed and load profile change. The effectiveness of the proposed system and controller in suppressing the existing voltage and frequency fluctuations in the traditional distribution power systems has become clear. Furthermore, the proposed FLC method is advantageous in preserving the reliable operation of the SMES system and protecting it from overloading and thermal stresses conditions.

4.2 Thesis 2

"An efficient control method for SMES has been proposed for improving the reliability of MGs in presence of RESs in both grid-connected and islanded modes of operation. In the MG islanded mode, the proposed method takes into consideration the sudden insertion of the WPG/PV unit as well as the sudden rejection of loads. For the grid-connected MG mode, two scenarios are studied to validate the proposed methods; PV-SMES grid-connected MG as a first scenario and the hybrid WPG/PV/SMES grid-connected MG as the second scenario. In both of the above mentioned scenarios, the proposed methods can significantly improve the MG reliability by mitigating power and voltage fluctuations, limiting the frequency variation in the islanded MG mode, minimizing the MG power losses, reducing the grid active/reactive power, and optimizing the SMES active and reactive powers to minimize the tie-line power flow between MG and main grid."

The related work is presented in Chapter 4 and 5 of the dissertation and has been published in [C4], [C8], [C9], [J5], [J6], and [J7].

In this thesis, a robust controlled-SMES scheme is proposed to enhance the reliability and stability of islanding MGs including wind power units and solar power generation as well. SMES can charge and discharge its stored energy to face the abnormal conditions during the islanding mode of the MGs distribution system.

In addition, two distribution systems have been examined as studied cases to validate the proposed methods. PV-SMES grid connected system and hybrid grid connected PV/wind/SMES MG system are tested with applying the proposed methods. Firstly, in the PV-SMES grid connected MG system, two methods, called FSM and OFSM, are investigated for minimizing the tie-line power of the MG and regulating the voltage at PCC. In the proposed methods, the reactive power of the VSC and the active charging/discharging power of the SMES are optimally and simultaneously computed. Therefore, the tie-line power flow has been effectively minimized, and the PCC voltage has been regulated. Furthermore, the fluctuations of tie-line power flow and the transmission power losses have been significantly decreased. Secondly, in a hybrid grid connected PV/wind/SMES MG system, a developed control technique to mitigate the fluctuations in voltage and power of grid connected hybrid renewable energy system due to weather conditions using SMES has proposed. The proposed FLC-SMES could reduce the fluctuation of active and reactive power transfer at the common connection point to a minimum value to achieve a self-supply for the loads only with cooperation between

HGS and SMES. Moreover, the voltage profile of the common point is regulated at the desired standard limitation (i.e. 1.0 pu), although the high changes of wind speed, PV radiation, and load profile, after FLC-SMES installation. The effectiveness of the proposed methods is proven by the fixed value 2.4 kV of the DC voltage of the capacitor connected to the chopper circuit with VSC during all charging and discharging processes

4.3 Thesis 3

"A developed coordination control between EVs and SMES systems is proposed to control the charging power required by electric vehicles and improve the power system performance. Four integration approaches of EVs with the grid are studied to exhibit their influence on the electrical network and to reduce power loss and voltage fluctuation. Furthermore, the growing load demand, management and support of active and reactive powers, and load balancing are discussed. Electricity price is a common coordination signal for both EVs and SMES control proposed method, which is based on the FLC technique. The simulation results show the effectiveness of the coordination control technique in minimizing power loss and voltage fluctuation. Furthermore, it helps to alleviate and reduce the active and reactive powers generated by the main grid."

The related work is presented in Chaptre 6 of the dissertation and has been published in [J3] and [C5].

In this thesis, a comprehensive analysis of the different EV integration approaches is presented. Four integration approaches are discussed and compared together as follows; uncontrolled charging, controlled charging, controlled charging/discharging, and controlled charging/discharging with SMES. FLC is used to make a coordination control between the EVs and SMES. The EVs have two FLC inputs and one output. The inputs are electricity price and SoC; the output depends on the case used. The output for Case 1 is charging power level and charging/discharging power level for Cases 2 and 3. Regarding the SMES control, there are two inputs and one output. The two inputs are the change in electricity price and the change in SMES current, the output is the duty cycle which is responsible for the SMES mode of operation. The simulation results show the difference between the four integration approaches. In addition, they prove that the proposed control strategy for the EVs and SMES is efficient. Through the comparison of the four types, controlled charging/discharging with SMES case achieves the best performance, this contribution can be summarized as follows: 1) Minimizing total system power loss. 2) Reducing the reactive power required from the grid by injecting reactive power to the grid from the SMES. 3) Preserving the PCC voltage at 1.0 pu, during peak loading events. 4) Decreasing total load power during the peak period by releasing active power from the SMES.

4.4 Thesis 4

"An improved coordination control strategy between the robust SMES based on FLC and the load frequency control (LFC) is proposed to emulate virtual inertia in the control loop of a realistic power system. The high penetration scenarios of RESs and the reduction in system inertia due to the increasing amount of RESs cause undesirable impact to power system dynamic stability, threaten the system security, and could lead to complete blackouts as well as damages to the system equipment. The proposed FLC strategy of SMES is coordinated with DFR for enhancement of the frequency stability and preservation of the system dynamic security due to the high penetration level of RESs. Moreover, the real system has been tested with considering different load and RESs disturbances with varying inertia level. The obtained results demonstrate that the proposed coordination strategy can effectively regulate the system frequency and maintain dynamic stability and security in admissible limits during contingencies cases."

The related work is presented in Chapter 7 of the dissertation and has been published in [J2], [J4], and [C3].

A new coordination strategy is proposed among the control functionalities and the control functionalities for low inertia power systems. The coordination strategy includes the LFC, SMES as virtual inertia emulator, and the digital frequency protection. Moreover, more practical modeling and a new FLC method have been developed for the SMES to emulate the virtual inertia characteristics. The Egyptian power system has been selected as a case study for investigating the proposed system. The results proved the superior performance of the proposed system for enhancing the security and stability for the studied power system, considering high penetration of RESs and insertion/rejection of loads. The results have demonstrated that the proposed FLC-SMES has achieved frequency stability robustly in the presence of high wind/PV power penetration, different load power fluctuations, and different levels of system inertia in all cases of the studied scenarios. The system stability is preserved in the obtained results with the reduction of the system inertia until 25% of its nominal value.

Moreover, the employed practical model and FLC method have helped at smooth and fast regulation of the system frequency compared to the simplified first-order model in the literature. The new proposed coordination strategy has achieved proper cooperative operation of the control and protection functionalities of the control center. The proposed coordination strategy with the FLC-SMES model can significantly reduce the spikes in the frequency during the overshoot and undershoot peaks as well as return to the steady-state value with short settling time. In the selected case study, the improvement of the frequency spikes reduction exceeds 50% over the conventional method for all tested scenarios

5. Significance and Practical Applicability of the Results

Here, we explain the importance and practical applicability of this research work. The control center of the transmission system operator (TSO) is supposed to incorporate the proposed real-time control strategy since it has the capability to receive and analyze the signals, generate proper commands, and transmit them over the power system. The recent developments in communication technologies can be incorporated in the proposed method to achieve two-way communication among the operator and the consumer and between the different DG systems. Thanks to the continuously decreasing cost of communication devices, and the spread of smart metering infrastructure, advanced and intelligent control systems can be developed for enhancing performance of the power system [1], [2]. The parameters monitored by the communication infrastructures include the power system parameters (e.g. demand power, frequency, voltages, currents, DGs power production, and switches status) and the environmental and other parameters (e.g. ambient temperatures, solar irradiance, wind speed, security or safety warning signals, etc.). Thence, in the proposed system, the digital control systems of the power electronic inverters that integrates the SMES, and RESs with the power systems, have the ability to send and/or receive the communication signals from power system control centers. Based on these signals, the digital controllers allow certain operating mode of the SMES and control the value of SMES current which flows to/from the grid to cover the optimal charging/discharging active power required according to the level of disturbance, the capacity and SoC of the SMES, and enhancing the system efficiency, reliability, and stability. Furthermore, the employed inverters perform additional functionalities for the power system, such as injecting/absorbing the optimal amount of reactive power according to the inverter capability. This, in turn, gives rise to the concepts of the smart inverter systems and advanced FLC that support the utility grid during subjected normal and abnormal conditions. Moreover, the optimal active and reactive power are simultaneously optimized to enhance the performance of the power systems (e.g. voltage fluctuations, frequency regulation, voltage rise, power loss, dynamic security, etc.).

The continual increase of the load demands and the run-out of fossil fuel, more integration, and installations of RESs has begun worldwide that have led to high penetration levels of RESs in power systems. However, RESs generated power depends on the environmental conditions that make them intermittent RESs units with the stochastic, uncertainty, and low inertia features into existing systems. This, in turn, leads to imposing several technical, financial, and regulatory obstacles [3]. These obstacles should be considered during the process of deciding the ESS size, developing control methods, and determining the highest permissible penetration level of RESs. Therefore, as a part of this work, we focused on the optimal integration and control methods of various RESs types and SMES for enhancing the inertia response and hence preserving the dynamic security of power systems for future high penetration levels of RESs. By using the available measured profiles of RESs, EVs, ESS, and loads for a practical power system, the proposed approach can determine the optimal integration levels and control system parameters of the power conversion structures of the power system. As a result, the benefits of RESs, SMES, EVs, etc., can be maximized while avoiding their operational obstacles.

6. List of Publications by the Author

Articles in international journals

[J1] **S.M. Said**, M. Aly, B. Hartmann, An Efficient Reactive Power Dispatch Method for Hybrid Photovoltaic and Superconducting Magnetic Energy Storage Inverters in Utility Grids, IEEE Access Journal (*Under review*).

[J2] **S.M. Said**, E.A. Mohamed, Mokhtar Aly, B. Hartmann, Coordinated Fuzzy-Logic Based Virtual Inertia Controller and Frequency Relay Scheme for Reliable Operation of Low-Inertia Power System, IET Renewable Power Generation (*Under review*).

[J3] H.S. Salama, **S.M. Said**, I. Vokony, B. Hartmann, Power System Improvement of Different Coordinated Electric Vehicles Integration Approaches with Superconducting Magnetic Energy Storage, International Review of Electrical Engineering. 14 (2019) 407-419.

[J4] **S.M. Said**, E.A. Mohamed, B. Hartmann, Coordination Strategy for Digital Frequency Relays and Energy Storage in a Low-Inertia Microgrid, Journal of Power Technologies. 99 (2019) 254–263.

[J5] **S.M. Said**, A. Ali, B. Hartmann, Tie-line Power Flow Control Method for Grid-connected Microgrids with SMES Based on Optimization and Fuzzy Logic, Journal of Modern Power Systems and Clean Energy. doi:10.35833/MPCE.2019.000282.

[J6] **S.M. Said**, H.S. Salama, B. Hartmann, I. Vokony, A robust SMES controller strategy for mitigating power and voltage fluctuations of grid-connected hybrid PV–wind generation systems, Electr. Eng. 101 (2019) 1019–1032. doi:10.1007/s00202-019-00848-z.

[J7] **S.M. Said**, M. Aly, B. Hartmann, A.G. Alharbi, E.M. Ahmed, SMES-based fuzzy logic approach for enhancing the reliability of microgrids equipped wit PV generators, IEEE Access. 7 (2019) 92059–92069. doi:10.1109/ACCESS.2019.2927902.

[J8] **S.M. Said**, B. Hartmann, Alleviation of extremely power and voltage variations caused by wind power and load demand using SMEs, Period. Polytech. Electr. Eng. Comput. Sci. 63 (2019) 134–143. doi:10.3311/PPee.13718.

[J9] **S. Said**, M. Aly, B. Hartmann, A robust SMES control for enhancing stability of distribution systems fed from intermittent wind power generation, Turkish J. Electr. Eng. Comput. Sci. 27 (2019) 3883–3898. doi:10.3906/elk-1810-10.

[J10] H.S. Salama, **S.M. Said**, I. Vokony, B. Hartmann, Adaptive Coordination Strategy Based on Fuzzy Control for Electric Vehicles and Superconducting Magnetic Energy Storage – Towards Reliably Operating Utility Grids, IEEE Transactions on Vehicular Technology (*Under review*).

[J11] M.M. Aly, M. Abdel-Akher, **S.M. Said**, T. Senjyu, A developed control strategy for mitigating wind power generation transients using superconducting magnetic energy storage with reactive power support, Int. J. Electr. Power Energy Syst. 83 (2016) 485–494. doi:10.1016/j.ijepes.2016.04.037.

[J12] M.M. Aly, E.A. Mohamed, H.S. Salama, **S.M. Said**, M. Abdel-Akher, Y. Qudaih, A developed Voltage Control Strategy for Unbalanced Distribution System during Wind Speed Gusts Using SMES, Energy Procedia. 100 (2016) 271–279. doi:10.1016/j.egypro.2016.10.177.

[J13] **S.M. Said**, M.M. Aly, M. Abdel-Akher, Capacity and Location Effects of Wind Turbine Energy Systems on Power Systems Stability, Int. J. Power Eng. Energy. 4 (2013) 343–347.

Peer Reviewed Conferences

[C1] **S.M. Said**, M. Aly, E.A. Mohamed, B. Hartmann, Analysis and Comparison of SMES Device Power Losses Considering Various Load Conditions, in: 2019 IEEE Conference on Power Electronics and Renewable Energy (CPERE), Aswan, Egypt, 2019: pp. 542-545.

[C2] **S.M. Said**, M. M. Aly, M. Abdel-Akher, B. Hartmann, Voltage Control of Large-Scale Distribution Systems during Wind Speed Transients, in: 2020 International Conference on Innovative Trends in Communication and Computer Engineering (ITCE), Aswan, Egypt, 2020: pp. 391-396.

[C3] **S.M. Said**, E.A. Mohamed, B. Hartmann, Enhancement of Microgrid Stability Using a Novel Scheme of Load Shedding Based-DFR Coordinated with SMES, in: 2020 International Conference on Innovative Trends in Communication and Computer Engineering (ITCE), Aswan, Egypt, 2020: pp. 359-364.

[C4] K.M. Kotb, **S.M. Said**, A. Dán, B. Hartmann, Stability Enhancement of Isolated-Microgrid Applying Solar Power Generation Using SMES Based FLC, in: 7th Int. Istanbul Smart Grids Cities Congr. Fair, ICSG 2019 - Proc., Institute of Electrical and Electronics Engineers Inc., 2019: pp. 104–108. doi:10.1109/SGCF.2019.8782321.

[C5] H.S. Salama, **S.M. Said**, I. Vokony, B. Hartmann, Impact of Different Plug-in Electric Vehicle Categories on Distribution Systems, in: 7th Int. Istanbul Smart Grids Cities Congr. Fair, ICSG 2019 - Proc., Institute of Electrical and Electronics Engineers Inc., 2019: pp. 109–113. doi:10.1109/SGCF.2019.8782335.

[C6] M. Nour, **S.M. Said**, A. Ali, C. Farkas, Smart Charging of Electric Vehicles According to Electricity Price, in: Proc. 2019 Int. Conf. Innov. Trends Comput. Eng. ITCE 2019, Institute of Electrical and Electronics Engineers Inc., 2019: pp. 432–437. doi:10.1109/ITCE.2019.8646425.

[C7] M. Nour, **S.M. Said**, H. Ramadan, A. Ali, C. Farkas, Control of Electric Vehicles Charging Without Communication Infrastructure, in: 2018 20th Int. Middle East Power Syst. Conf. MEPCON 2018 - Proc., Institute of Electrical and Electronics Engineers Inc., 2019: pp. 773–

778. doi:10.1109/MEPCON.2018.8635277.

[C8] **S.M. Said**, B. Hartmann, A robust controlled-SMES for islanding microgrid distribution systems, in: Proc. - 2018 6th Int. Istanbul Smart Grids Cities Congr. Fair, ICSG 2018, Institute of Electrical and Electronics Engineers Inc., 2018: pp. 139–143. doi:10.1109/SGCF.2018.8408959.

[C9] E.A. Mohamed, **S.M. Said**, B. Hartmann, Y. Mitani, An Efficient Fuzzy Logic Controlled-SMES for Isolated-Microgrid System Considering High Wind Power Penetration, in: 2018 5th Int. Conf. Electr. Power Energy Convers. Syst. EPECS 2018, Institute of Electrical and Electronics Engineers Inc., 2018. doi:10.1109/EPECS.2018.8443537.

[C10] **S.M. Said**, A. Selim, B. Hartmann, Enhancement of voltage profile for unbalanced distribution system with wind energy and superconducting magnetic energy storage, in: Proc. 2018 Int. Conf. Innov. Trends Comput. Eng. ITCE 2018, Institute of Electrical and Electronics Engineers Inc., 2018: pp. 389–395. doi:10.1109/ITCE.2018.8316640.

[C11] **S.M. Said**, M.M. Aly, B. Hartmann, Application of SMES for voltage control of power systems with high wind power penetration, in: Proc. 2018 Int. Conf. Innov. Trends Comput. Eng. ITCE 2018, Institute of Electrical and Electronics Engineers Inc., 2018: pp. 461–466. doi:10.1109/ITCE.2018.8316667.

[C12] **S.M. Said**, B. Hartmann, M.M. Aly, M. Mosa, R.S. Balog, Comparison between operating modes of distributed generation on voltage profile and stability of distribution systems, in: 2018 IEEE Texas Power Energy Conf. TPEC 2018, Institute of Electrical and Electronics Engineers Inc., 2018: pp. 1–6. doi:10.1109/TPEC.2018.8312107.

[C13] **S.M. Said**, M.M. Aly, M. Abdel-Akher, Application of superconducting magnetic energy storage (SMES) for voltage sag/swell supression in distribution system with wind power penetration, in: Proc. Int. Conf. Harmon. Qual. Power, ICHQP, IEEE Computer Society, 2014: pp. 92–96. doi:10.1109/ICHQP.2014.6842877.

[C14] **S.M. Said**, M. Aly, M. Abdel-Akher, Application of Superconducting Magnetic Energy Storage (SMES) to Improve Transient Stability of Multi-Machine System with Wind Power Penetration, 16th Int. Middle-East Power Syst. (2014). https://scholar.google.com/scholar?hl=en&as_sdt=0,5&cluster=5552545982052428418.

[C15] M. M. Aly, **S.M. Said**, and M. Abdel-Akher, Comparison Between Wind Turbine and Static Var Compensator for Power System Stability, in: Proc. 5th Int. Middle East Power Syst. Conf. (MEPCON'12), Alexandria University, Egypt, 2012.

7. References

[1] G. Artale *et al.*, "A new low cost power line communication solution for smart grid monitoring and management," *IEEE Instrum. Meas. Mag.*, vol. 21, no. 2, pp. 29–33, Apr. 2018.

[2] O. Tan, D. Gunduz, and H. V. Poor, "Increasing Smart Meter Privacy Through Energy Harvesting and Storage Devices," *IEEE J. Sel. Areas Commun.*, vol. 31, no. 7, pp. 1331–1341, Jul. 2013.

[3] *Distributed Power Generation: Planning and Evaluation*. CRC Press, 2000.