TECHNO-ECONOMIC ANALYSIS OF INTERMITTENT RENEWABLE ENERGY PENETRATION WITH THE PROPOSED INDIA-SRI LANKA HVDC INTERCONNECTION

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Degree of Master of Science

Department of Electrical Engineering

University of Moratuwa

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Dissertation submitted in partial fulfillment of the requirements for the degree

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DECLARATION

"I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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The above candidate has carried out research for the Masters dissertation under my supervision.

……………………… ………………………

Signature of the supervisor Date

Dr. W.D.A.S. Rodrigo

DEDICATION

To my family

ACKOWLEDGMENT

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ABSTRACT

This research is a techno-economic analysis carried out to identify the effect of level of intermittent renewable energy penetration in to the Sri Lankan power system with the proposed India-Sri Lanka HVDC interconnection. The focus on power generation using intermittent renewable energy gives rise to system operational issues leading to renewable energy curtailments. This research adopts a methodology to identify the level of RE penetration with the HVDC link compared to original power system planned with pump storage power plant.

Future power plant additions based on least cost principles are obtained using WASP software considering stage development of HVDC; 500 MW in 2025 and 1000 MW in 2028. This power plant schedule was input to long term dispatch simulation software SDDP in order to obtain the optimum hydro thermal generation mix for different seasons of the year namely, high wind and wet periods. Output of SDDP for each season was input to short term dispatch simulation software NCP in order to simulate the daily dispatch and obtain renewable curtailments to identify the RE penetration level. Renewable are modeled in detail with 30 minute resolution in the dispatch simulation software. This process was repeated to obtain the RE penetration level with 500 MW HVDC and 1000 MW HVDC for different scenarios assuming aggressive wind development, aggressive solar development and mix development.

The economic analysis was carried out to identify the cost impact of each scenario compared to the original power system. It was observed that the HVDC is economical for the initial RE capacities but the RE penetration can be increased with HVDC at an additional cost to the system. Therefore, sensitivity analysis was carried out to identify at what variable cost of HVDC the link would bring economic benefit to the country for each scenario. This methodology could be used when negotiating the pricing contract agreements with India to identify whether the HVDC link could bring economic benefit to Sri Lanka depending on the prevailing energy mix.

Keywords: HVDC, Intermittent Renewable Energy

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LIST OF ABBREVIATIONS

CEB	-	Ceylon Electricity Board
CSC	-	Current Source Converters
FIT	-	Feed-in-tariff
HVDC	-	High Voltage Direct Current
LDC	-	Load Duration Curve
LTGEP	-	Long Term Generation Expansion Plan
MMbtu	-	Million British Thermal Unit
O&M	-	Operation & Maintainance
ORE	-	Other Renewable Energy
PSPP	-	Pumped Storage Power Plant
PV	-	Present value
RE	-	Renewable Energy
SDDP	-	Stochastic Dual Dynamic program
SLSEA	-	Sri Lanka Sustainable Energy Authority
Solar_H	-	Solar Hambanthota
Solar_K	-	Solar Kilinochchi
SPPA	-	Small Power Purchase Agreement
VRE	-	Variable Renewable Energy
VSC	-	Voltage Source Converters
WASP	-	Wien Automation System Package
Wind_E	-	Wind Eastern
Wind_H	-	Wind Hill country
Wind_M	-	Wind Mannar
Wind_N	-	Wind Northern
Wind_P	-	Wind Puttalam