

## PREFACE

The nascent advances in technology and the global emphasis on sustainable development through clean and green power sources are transmuting the conventional analysis, monitoring, and control aspects of the power sector. Traditionally, the power system was mainly comprising of generation utilities, transmission utilities, and distribution utilities vertically integrated with centralized generation and unidirectional power flow. The power flow was primarily directed from Power generating sources to industrial, residential, commercial, or agricultural loads through the transmission network. Later, with the introduction of open access and deregulation, the monopolistic and centralized system transformed into a decentralized and horizontally integrated system. This enabled the independent power producers to inject and sell Power to the grid.

The introduction of deregulation and open access brought a competitive environment among the generation and distribution sector and complicated the task of independent system operators. The enhanced emphasis on distributed generation with high dependence on PV and Wind-based sources under both grid-connected and off-grid modes provided the consumers with the ability to meet their requirements and sell back locally or to the grid. Such consumers are being termed as prosumers.

Under the prevalence of Distributed Energy Resources (PV and Wind) and Virtual Power Plants (Electric Vehicles), there are chances of a reversal of Power from Active Distribution Networks to the transmission and sub-transmission levels. In such circumstances, the conventional notion of segregated analysis of transmission and distribution would not remain viable. The authenticity of the T&D system's segregated analysis could be challenged because the phenomena happening at the transmission level

would now be affected by those occurring at the distribution level and vice versa. Thus, adequate frameworks for analyzing the integrated analysis of T&D systems need to be developed.

The overall power system's exact situational awareness has always been vital for adequate power system operation. Available Transfer Capability (ATC) is an indicator of the remaining transfer capability in the system. The availability of information pertinent to ATC would empower the system operator to take the most techno-economically feasible decision. In this research work, we have promulgated: -

- ATC assessment and enhancement methodology.
- The Pseudo-PMU (PPMU) emulation for quasi-static analysis and offline data generation of power systems has been developed.
- A framework for real-time ATC assessment has been proposed.
- ATC assessment of Integrated Transmission and Distribution.
- ATC assessment of Integrated Transmission and Distribution (ITD) considering Electric Vehicles and Microgrids as an element of Active Distribution System (ADS).
- Energy transaction using the blockchain-based framework and its impact on Aggregated Load Profile and Available Distribution Capability has been discussed.

The first part presents a method for ATC assessment and enhancement. The problem of ATC assessment has been solved by using pattern search optimization. The Flexible AC Transmission System (FACTS) devices can modulate the power flow through the lines and be optimally tuned to enhance the system's ATC. The devices, namely TCSC and SVC, have been considered and modeled, and the method for determining optimal operational strategies for maximizing the ATC of the system has been inked.

To develop the real-time ATC assessment technique based on Artificial Neural Networks (ANN), extensive training and testing data sets would be required. The synchrophasor measurement devices are capable of providing time-synchronized measurements across the grid. Such information could be considered as a first information report of events happening in the system. The measurement information could be directly utilized for various monitoring, control, and protection applications. Thus, for offline simulation gathering, PMU data was an issue; a pseudo-PMU emulation method has been developed and presented in the second part to tackle this issue.

In the third part, an ANN-based ATC estimator has been developed. The proposed method employs the radial basis neural network for estimating the ATC. The methodology involves feature extraction and linear state estimation. The developed method has also been tested on a real-time testbed using a Real-Time Digital Simulator (RTDS). The OPENECA software has been used to acquire the PMU measurement from the 'GTNET PMU' available in RTDS to MATLAB script, where the developed ATC estimator is employed to estimate the ATC.

Understanding the effect of large-scale deployment of distributed energy resources requires the development of a framework for integrated analysis of T&D analysis. Therefore, a multi-agent-based framework for integrated analysis of transmission and distribution systems has been propounded in the fourth section. The developed technique has been to assess the effect of ADN on the ATC of the system. The ADN employs CVR as a Volt-VAR optimization tool, and the impact of the same has also been assessed.

Advancing the research further, in section fifth, the effect of the presence of Electric Vehicles (EVs) capable of acting as Virtual Power Plants (VPP's) and microgrids capable of withdrawing/injecting Power to the ADN have been considered. Two indices, namely

ATCVR and ATCE factor, have been proposed as measures to assess the overall impact of considering the ADN on the ATC of the System.

The advent of the decentralized ledger and computing technology with cryptographic security paves the way to a new market structure where the various market participants could bid and actively participate in the bid settlement process. The sixth part of the work is dedicated to assessing the application of blockchain-based energy trading in IoT (Internet of Things) rich ADS and its probable impact on ADC as well as aggregated load profile of the ADS.