Error Control and Minimization across UPFC Controller using ANN Layer Modelling

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Abstract- The report recommended that UPFC be used instead of FACT in power systems for reactive power compensation, voltage stability, and control. The UPFC's key benefit in three phase line compensation is that it is integrated into a Unified or Generalised power flow controller. This work offers a simple approach for managing actual and reactive power flow, as well as a comparison analysis of standard power flow controllers such as UPFC and Observation of UPFC throughout Error level utilising ANN layer system block. This report proposes a simulation examination of all the controllers separately using the MATLAB simulation tool.

Keywords: FACTS, UPFC, VSC, PSS, real and reactive power flow.

Introduction

An rising number of high power semiconductor devices are available for power system applications, notably in flexible ac transmission systems (FACTS) equipment, due to recent advances in their diversity and ratings [1]. The unified power flow controller (UPFC) is a recently introduced FACTS device. The actual and reactive power flows in a transmission line may be adjusted quickly and precisely using this gadget. The UPFC is made up of two voltage-sourced converters (VSCs) that use gate turn-off thyristors (GTOs) and are powered by a common dc-circuit that includes a dc-storage capacitor (Fig. 1). The UPFC may be divided into two branches: parallel and series.

Each converter may absorb reactive power on its own. This configuration allows active power to flow freely in either direction between the ac-terminals of the two converters. The parallel converter's role is to supply or absorb the active power required by the series branch. A parallel-connected transformer connects this converter to the ac terminal. It may also inject leading or lagging reactive power straight into the connecting bus bar if necessary. The major function of the UPFC is provided by the second (series connected) converter, which injects an alternating current voltage with controlled magnitude and phase angle. This voltage source conducts transmission line current, resulting in an active and reactive power exchange with the ac-system.

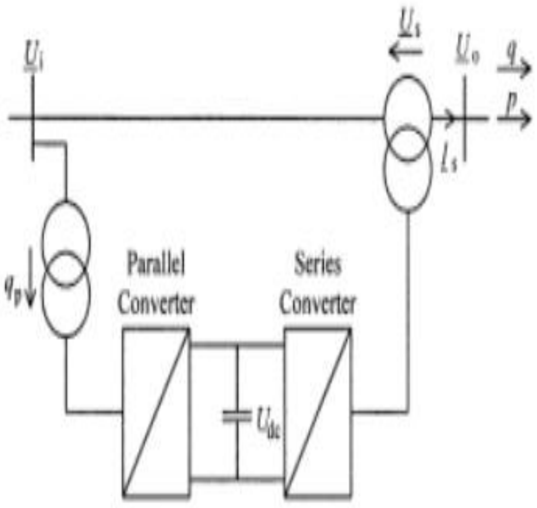

Fig.1. Unified power flow controller.

Although the UPFC's steady-state and transient behaviour have been characterised in the literature, nothing is known about its frequency response characteristic. When the UPFC is integrated in a larger network, this property is useful for recognising possible resonance concerns. The primary goal of this work is to obtain such a feature.

I. Research Motivation

Greater demands have been placed on the transmission network in recent years, and these needs will continue to rise due to a growth in the number of nonutility producers and increased competition among utilities themselves. Increasing transmission demand, a lack of long-term planning, and the necessity to give open access to producing businesses and customers have all contributed to a trend towards less security and lower supply quality. FACTS technology is critical to alleviating some, but not all, of these issues by allowing utilities to get the most out of their transmission systems and improve grid resilience.

On the other hand, as power transfer increases, the power system becomes more complex to operate, and the system becomes less secure for riding through major outages. Large power flows with insufficient control, excessive reactive power in various parts of the system, large dynamic swings between different parts of the system, and bottlenecks may result. Because of increased power demand, modern power system networks are operating under highly stressed conditions.

As a result, meeting reactive power requirements, particularly during contingencies, has become difficult, as has keeping the bus voltage within acceptable limits [4]. Voltage instability in the system typically manifests itself as a progressive decrease in voltage magnitude at some of the buses. Voltage instability can result in loss of load in an area or tripping of transmission lines and other elements by their protective systems, resulting in cascaded outages and voltage collapse in the system [5,6].

Major changes have been made to the structure of electric power utilities all over the world in recent years. The reason for this was to improve the efficiency of the power system's operation by deregulating industry and opening it up to private competition. This is a global trend, and similar structural changes have occurred in other industries, such as telecommunications and airline transportation. As a result of these changes, the transmission, generation, and distribution systems must now adapt to a new set of rules.

The open market rules. Additionally, adaption to new generation patterns will necessitate adaptation as well as enhanced flexibility and availability of the system. The power sector has responded to these issues by developing flexible AC transmission system (FACTS) technology. This word may refer to a full family of power electronic controllers, some of which have reached maturity in the industry while others are still in the design stage.

Iii. Research Contributions

The contributions of the study are manifold:

It offers various well-designed taxonomies for UPFC, which can aid in understanding the fascinating correlations that exist between numerous variables and ideas in the area. These categories cover UPFC converter topologies, UPFC and D-UPFC applications, UPFC steady state and dynamic models, UPFC control techniques, UPFC allocation methods, and UPFC simulation tools. UPFC control methods, for example, include linear and linearised control, advanced control, decoupled control, vector control, preventive control, coordinated control, sliding mode control, robust control, adaptive control, hybrid control, and intelligent control, which includes neural network (NN), fuzzy logic, genetic algorithm, particle swarm optimisation (PSO), and hybrid systems, according to the introduced taxonomy.

It sets the future research goals of cost reduction, new cost-effective UPFC topologies and architectures with experimental validation, UPFC control algorithms with reconfigurable architecture, wide area coordinated control algorithms, and new models, methods, and simulation tools for integrating UPFCs into smart power system operations and planning.

It is intended to serve as a guide for researchers and engineers interested in the present models and approaches, as well as future research trends in the control, analysis, operation, and planning of UPFCs in smart power systems.

Iv. Unified Power Flow Controller (Upfc)

During instabilities, the Unified Power Flow Controller (UPFC) is a power electronic designed controller that provides fast and quick reactive power adjustment reaction at high voltage level electric transmission networks. In UPFC, a pair of three phase regulated bridges is used to generate an AC current. This alternating current current is sent into the transmission line via a series transformer. Following the injection of AC current into the transmission line, it is possible to advance the active and reactive power flow in the transmission line.

The UPFC contains solid state power electronics devices such as GTO, IGBT, and others that provide multipurpose flexibility to the power system, whereas traditional control systems rely on thyristors, which do not provide such versatility. L. Gyugyi devised the UPFC concept in 1995. The UPFC is a mutual FACT technology that consists of a static synchronous series compensator (SSS) and a static synchronous compensator (STATCOM) that are linked by a common DC voltage connection (a capacitor).The UPFC performs a secondary but critical function in power system stability control, dampening undesirable system oscillations and advancing power system transient stability [6].

The Unified Power Flow Controller (UPFC) is a multipurpose controller that is well-known for simulating multiple functions at once. It maintains the power flow level throughout the power system's transmission lines by managing the voltage magnitude. UPFC can play an important role in the continuous and dynamic operations of power system networks by providing many advantages during such operations. With the discovery of UPFC, new difficulties in power electronics and power system design have arisen. UPFC's core configuration consists of two voltage source convertors (VSC), one of which is connected in series with the transmission line (coupled with SSSC) and the other in parallel with the transmission line (coupled with STATCOM). The UPFC is in the works.

In comparison to conventional power transmission technology, the UPFC is capable of controlling, either selectively or instantly, all parameters that directly affect power flow in the transmission line (i.e. impedance, voltage, and phase angle), and this main role distinguishes it from other FACTS devices. It is capable of independently managing both reactive and active power in the gearbox line. The UPFC not only serves as a replacement for disparate controllers and regulators such as STATCOM, TCSC, SSSC, and phase angle shift regulator, but it also provides other flexible flexibilities by combining the various functionalities of these controllers.

GyuGyi, as previously stated, proposed the UPFC concept in 1991. The UPFC was designed for real-time control and dynamic compensation of alternating current transmission networks. It offers multifunctional versatility to address many of the difficulties confronting the power supply businesses. All of the parameters impacting power flow in the power system network (e.g., voltage, phase angle, and impedance) can be controlled synchronously or separately using UPFC. As a result, the adjective "unified" [1] announces this one-of-a-kind capability. The capacity to power flow bi-directionally while retaining well-regulated DC voltage and workability in a wide range of operating situations are the major reasons for UPFC's global dissemination.

This is the second or most recent iteration of FACTS technology. This FACTs device combines the features of two existing FACTS devices, STATCOM (static synchronous compensator) and SSSC (static synchronous series compensator). These devices are essentially voltage source converters (VSCs).The UPFC is an SVS (usually synchronous voltage source). Typically, the SVS exchanges both reactive and actual power with the gearbox system. To be honest, an SVS can only generate reactive power that is traded; real power must be provided to it or absorbed from it by an appropriate power supply or link [1].

V. Converter Topologies

There are two types of UPFC converter topologies: (i) multi-pulse converters and (ii) multi-level converters. The multi-pulse converter has lower total harmonic distortion but higher transformer complexity than the multi-level converter for a given power. Multilevel converters for UPFC are divided into three types: (i) multipoint-clamped converters (MPCs) or diode-clamped converters [5,] (ii) chain converters or cascade converters [8, 4], and (iii) nested-cell converters or flying capacitor converters [4]. Because three-level MPCs provide a wide range of voltage regulation, they are used in the UPFC projects at Inez and Kangjin [7].

A chopper stabilised diode-clamped seven-level converter UPFC. [1] Investigates a UPFC employing three neutral-point-clamped (NPC) multilevel converters. [4] Investigates a UPFC based on flying capacitor multi-level VSCs with phase-shifted sinusoidal pulse width modulation (SPWM) control and insulated gate bipolar transistor (IGBT) technology. [20] presents a conceptual architecture of a UPFC with SPWM control and VSCs employing either gate turn-off thyristors or IGBTs.

In compared to the typical UPFC with two VSCs and two transformers, the transformer-less UPFC with two cascade multi-level converters has major advantages, such as cheap cost, low weight, high reliability, and fast dynamic response.

Vi. Control Strategy

Generally a control methodology should have the accompanying characteristics:

1. Steady state objectives (i.e., real & reactive power flows) should be instantly achievable by setting the references of the controllers.

2. Dynamic & transient stability enhancement with the aid of the controller references.

Power system stability is the ability of an electric power system, for a given initial working condition, to recoup a state of working harmony after being subjected to a physical disturbance, with most system factors having limits so that the entire system remains in equilibrium condition. The stability of the power system remains a fundamental concern in system operation. Under typical operating conditions, the speed of the large number of generators remains basically constant throughout the system. The synchronous operation of a system is defined as any minor or big scale disruption that can disrupt this synchronous function.

For example, there could be a rapid increase or decrease in load or a loss of generation. Another type of interruption is the switching out of a transmission line, which can occur as a result of overburdening or a line failure. Depending on the magnitude and location of origin, the disruption might be classified as small or major. Small fluctuations in load or generation cause the minor disturbances. Large disruptions are caused by transmission line defects, unexpected load changes, loss of generating units and line switching out [13],[14]. Power fluctuations between the generating units and the electrical network system will result from a disruption in the electrical system.

Vii. Upfc Operation

The UPFC is made up of two voltage-sourced converters, labelled VSC1 or "Converter 1" and VSC2 or "Converter 2" in the diagram, and is powered by a dc storage capacitor Vdc [Fig.]. It injects an alternating current series voltage into the transmission line and controls power flow by adjusting the amplitude and phase of the infused voltage. The series inverter is programmed to inject a series of synchronous voltages, V, into the line. During this period, the series inverter will exchange real and reactive power with the line. The reactive power is provided electronically by the series inverter, while the real power is transmitted to the dc terminals.

The shunt inverter works by requesting dc terminal power (positive or negative) from the line and so adjusting the voltage of the dc bus. As a result, the total real power consumed from the line by the UPFC is equal to the losses of the two inverters and their transformers. The remainder of the shunt inverter's capability can be used to exchange reactive current with the line. The shunt inverter is designed to draw a regulated current from the line. One element of this current is naturally controlled by the need to modify the series inverter's true power. The leftover current is reactive and can be tuned to any desired reference point (inductive or capacitive).

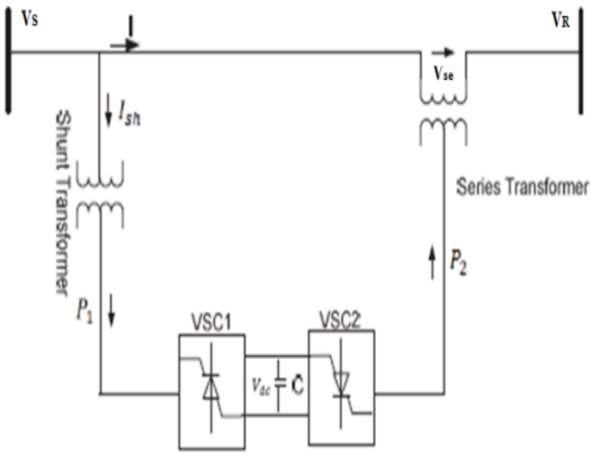

Fig 2. UPFC Connection diagram.

Artificial Neural Network

One of the most important tools in machine learning is artificial neural networks. They are brain-inspired systems designed to mimic how humans learn, as the "neural" portion of their name suggests. Neural networks are made up of input and output layers, as well as (in most cases) a hidden layer made up of units that turn the input into something usable by the output layer. They're great for detecting patterns that are far too complex or numerous for a human programmer to extract and train the computer to recognise.

Let's dive into the mathematics part and see the backpropagation working with feedforward and feed backward Neural Network in depth.

Approach

Step 1: Randomly initialize the Weights to a small number close to 0 (but not 0).

Step 2: Input the first observation of your dataset in the input layer, each feature in one input node.

Step 3: Forward-Propagation: from left to right, the neurons are activated in a way that the impact of each neuron's activation is limited by the weights. Propagates the activations until getting the predicted result y.

Step 4: Measure the generated error.

Error Analysis

Formally, error analysis refers to the practice of reviewing dev set examples that your algorithm misclassified in order to determine the root causes of the problems. This can help us priorities which problems require attention and how much attention they require. It points us in the right way for dealing with the errors.

Error analysis is more than simply a last-ditch effort. It should be incorporated into mainstream development. We usually begin with a small model, which is bound to have low accuracy (high error). Then we may begin analysing this model and analysing the flaws. We may evolve with the model as we analyses and correct such flaws.

Viii. Result And Simulation

This chapter presents simulation results obtained in MATLAB Sim Power System. The outcome and simulation are then followed by talks and an evaluation that includes load flow analysis as well as power system performance under condition. The simulation included a bus test system without FACTS controllers, which implies that it only measured the system's behaviour during a fault situation by applying a three-phase fault to the system, without the FACTS compensation effect. The performance of a system was then measured using UPFC.

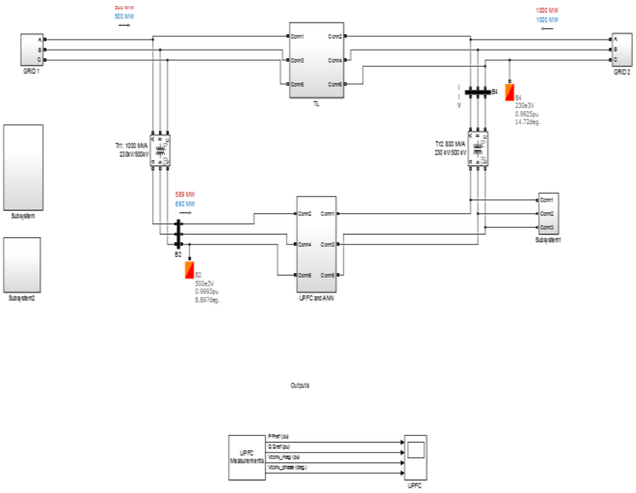

Fig 3. UPFC based System model.

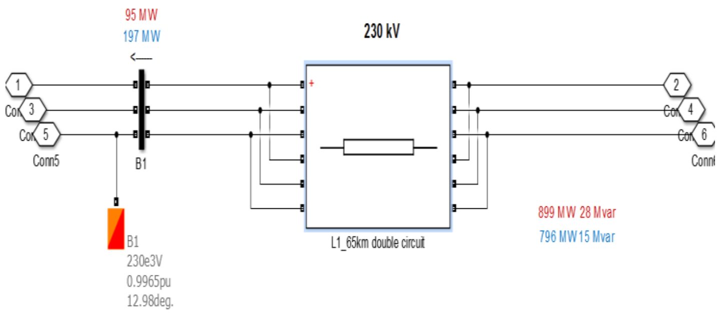

Fig 4. Transmission line.

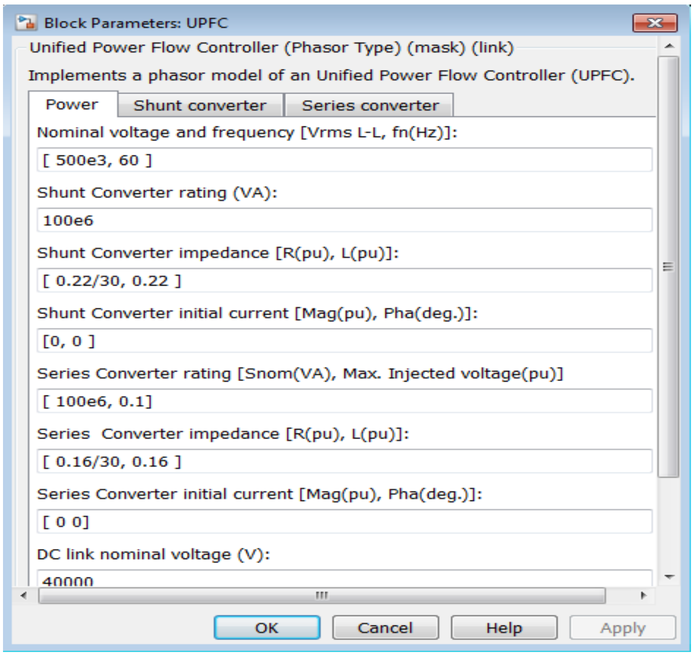

Fig 5. UPFC Parameters Nominal voltage, impedance and initial current and DC link voltage.

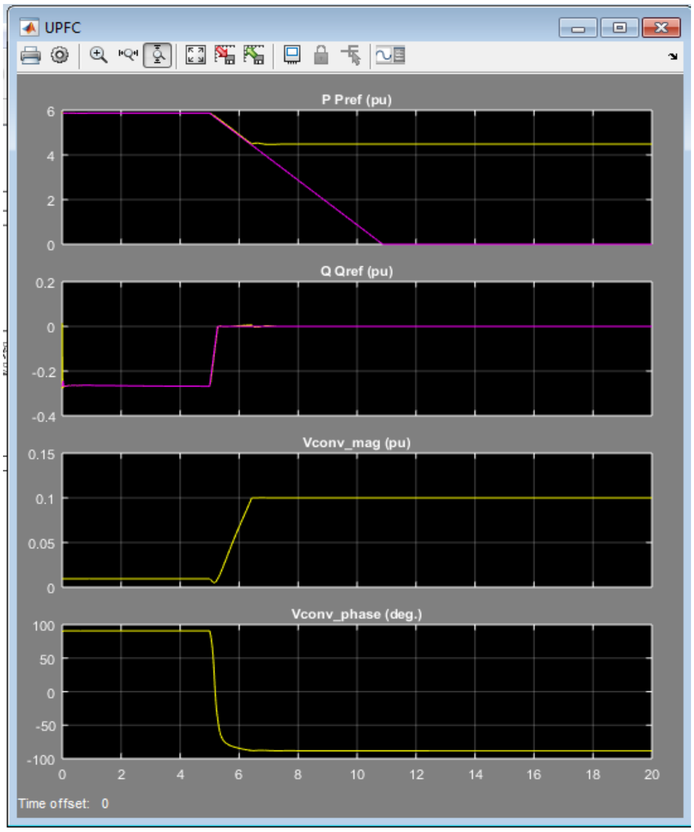

Fig 6. UPFC Power stabilization per unit curve.

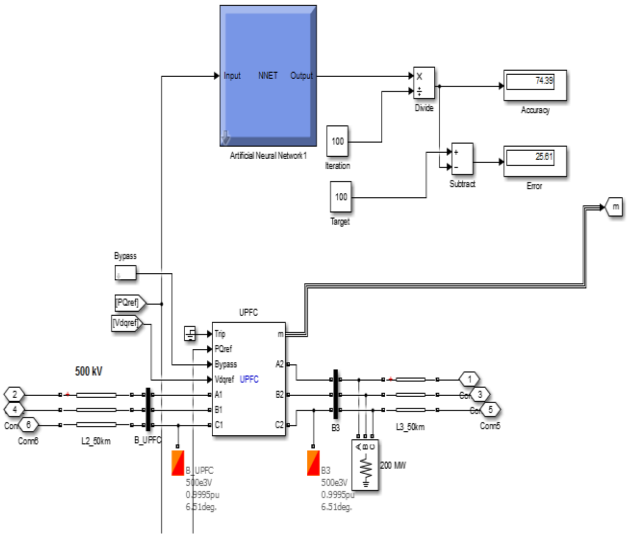

Fig 7. UPFC across Error and Accuracy of power stabilization.

Ix. Conclusion

UPFC allows dynamic management of line parameters, resulting in smooth and effective power flow regulation. The Unified Power Flow Controller can also be utilised as a generalised power flow controller that can maintain the required real and reactive power flow at the corresponding ac line buses. UPFC in a power system can achieve improved accuracy (74.39%) and reduced error (25.60%) flexibility in controlling ac power transmission of a grid.

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