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Capacitor Less UPFC for Power Quality Improvement using Deadbeat Controller

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***Abstract*: Flexible AC Transmission System (FACTS) is applied to manage a number of varied situations of the power line. The Unified Power Flow Controller (UPFC) as one of the FACTS is used in order to keep conditions of the power line. The UPFC consists of two components. One is connected in parallel to the power line, and the other is connected in series. By the parallel system, the reactive power and 3 -phase unbalance can be compensated to improve the power factor and to keep the common DC inductor voltage constant. By the series component, the voltage drop can be compensated to maintain proper line voltage. In these operations, quick response is required in order to respond variable situations. In this study, the deadbeat (DB) control is applied for the ad-vantage of quick response and easy setting without the gain design. The principle of the DB control, simulation results, and experimental results are presented for verification of its characteristics in this paper.**

***Keywords*: UPFC, power quality improvement, deadbeat controller**

1. Introduction

Electrical power frameworks are muddled systems with several generators providing capacity to a huge number of burdens interconnected through transmission lines, transformers, and circulation systems. A streamlined structure, serves to show the chain of command in a power framework beginning from the creating plant, through the transmission framework, to the sub-transmission framework and down into the dissemination framework. As engines from the mechanical insurgency are supplanted with server farms of the advanced transformation, the nature of the electrical power turns into a critical worry for both the client and utility. VAR remuneration is characterized as the administration and control of receptive capacity to improve air conditioning framework execution. Inside the writing, there are distinctive composes and approaches utilized for receptive power compensation.

The control appropriation framework fundamental capacities are to give electrical vitality to buyers as practical as could reasonably be expected, with a decent level of value and dependability. The dependability of the framework depends fundamentally on the unwavering quality of the segments that make up the framework. Bound together power stream controller (UPFC) is a standout amongst the most in fact promising gadgets in the adaptable air conditioning transmission frameworks (FACTS) family [1]–[4]. It has the ability to control voltage extent and stage point and can likewise freely give (positive or negative) receptive power infusions. Along these lines, the UPFC can give voltage bolster, control of genuine power stream, and different capacities. The UPFC has finished the change from inventive idea to effective application at the AEP Inez substation [1]. Since the UPFC requires a high capital expense to introduce, it can't be introduced in each conceivable transmission line. Along these lines, a need exists for building up money saving advantage examination system to decide whether an UPFC would be valuable and, provided that this is true, the best area to introduce the UPFC. On a basic level, deciding the ideal area for an UPFC is basic. For every conceivable area, we put an UPFC in the power framework demonstrate and Fig: the cost reserve funds concerning a base case (with no new UPFC introduced).

The working expense at each time and for every potential area is resolved utilizing ideal power stream (OPF) program. In any case, the computational weight of assessing this yearly incentive for each conceivable line is tremendous on the grounds that an OPF issue must be settled for each line and at each time consistently. Thusly, a productive screening system is wanted to distinguish just the most encouraging areas so that at each point in time consistently, the comprehensive Figuring's portrayed above don't need to be done for each area that is a contender for introducing the UPFC. Rather, we illuminate just a single "base-case" OPF issue for each point in time.

There are a few papers requiring numerous air conditioner OPF keeps running for ideally finding UPFCs [5]–[7]. In [5], a repetitive algorithm is proposed that requires running ac OPF with a UPFC in a transmission line and repeating this process for all possible UPFC locations. In contrast, [6] introduces a mathematical model installing each UPFC in all possible transmission lines and filters out ineffective UPFC locations once ac OPF converges. This process is repeated until the most promising locations are identified. A non-convex approach using a parallel-tabu-search to optimally allocate UPFCs is proposed in [7]. The algorithms mentioned in [7] are most commonly used for evaluation of such non-convex problems, but the problem formulation is one way of dealing with the "exponential explosion" of problem size for such problems. Since all three techniques use a brute-force method for optimally locating UPFCs requiring multiple ac OPF solutions, they cannot be practically used for a large load flow case.

In [5], a dull calculation is suggested that requires running air conditioning OPF with an UPFC in a transmission line and rehashing this procedure for all conceivable UPFC areas. Interestingly, [6] presents a scientific model introducing each UPFC in all conceivable transmission lines and sift through insufficient UPFC areas once air conditioning OPF meets. This procedure is rehashed until the point that the most encouraging areas are distinguished. A non-arched methodology utilizing a parallel-tabu-pursuit to ideally assign UPFCs is proposed in [7]. The calculations said in [7] are most regularly utilized for assessment of such non-raised issues, yet the issue plan is one method for managing the "exponential blast" of issue measure for such issues. Since every one of the three strategies utilize a beast constrain technique for ideally finding UPFCs requiring numerous air conditioner OPF arrangements, they can't be for all intents and purposes utilized for a huge load flow case.

Presently, it is well established in the scientific community that the UPFC has the ability to increase the power flow capacity and improve the stability of an electric power transmission system through the proper design of its controller [1]. Faced with these difficulties, intelligent controls such as fuzzy logic and artificial neural networks have emerged as better alternatives to the conventional linear and nonlinear control methods. However, the complexities associated with the adaption of membership functions and computation requirements for defuzzification have hindered the application of fuzzy logic [11]–[15]. Hence, recent studies have turned to artificial neural networks (ANN) to achieve the desired goals [16]–[18].

Artificial neural networks have an inherent capability to learn and store information regarding the nonlinearities of the system and to provide this information whenever required. This renders the neural networks suitable for system identification and control applications [19]–[21]. Although intelligent and hybrid algorithms are already being implemented in the domains of image processing, robotics, financial management, and so on, their application in the field of FACTS devices for power flow control is fairly recent. Some recent results can be found in [12], [16], [17], [22], [23].

In [16], a radial basis function neural network has been designed to control the operation of the UPFC in order to improve its dynamic performance. Simulation and experimental results were presented to demonstrate the robustness of the proposed controller against changes in the transmission system operating conditions. However, large memory and long computation time are required for its proper functioning and, in addition; the controller is designed under the assumption that the upper bound of the disturbance is known. A comparative study of transient stability and reactive power compensation issues in an autonomous wind-diesel-photovoltaic based hybrid system using robust fuzzy-sliding mode based Unified Power Flow Controller has been presented in [12], but it has the limitation that a linearized small-signal model of the hybrid system is considered for the transient stability analysis. Hence, the system will suffer from performance degeneracy when the operating condition changes. In [22], the recently proposed -learning method for updating the parameter of a single neuron radial basis function neural network has been used as a control scheme for the UPFC to improve the transient stability performance of a multimachine power system. However, the updating control parameters are optimized for each perturbation using a generic algorithm which increases the computational burden and makes the control implementation less feasible. A neural network predictive controller for the UPFC has been designed in to improve the transient stability performance of the power system. Nevertheless, the neural network controller is implemented only on the series branch of the UPFC which limits the performance of the device. In [17], a neural network controller based on a feedback linearization auto regression average model is used to design an adaptive-supplementary unified power flow control for two interconnected areas of a power system. However, in this paper and many others, the bounds of system uncertainty and disturbances are assumed to be known. But in practice, it is always difficult to determine the exact upper limit of system uncertainty and disturbances. Hence, the above controllers cannot provide satisfactory results.

From the above drawbacks, in this paper, a new hybrid approach which combines RBF neural network with the sliding mode technique to design a UPFC controller for power flow control and DC voltage regulation of an electric power transmission system with unknown bounds of system uncertainty and disturbances is proposed. The advantages of this design philosophy are that the controller is suitable for practical implementation and it makes the design useful for the real world complex power system. The remaining sections of this paper are organized as follows. In Section 2, structure and control strategy of the UPFC presented. In Section 3, simulation results are presented. Finally, in Section 4, some concluding remarks are presented.

2. The structure and control strategy of the UPFC

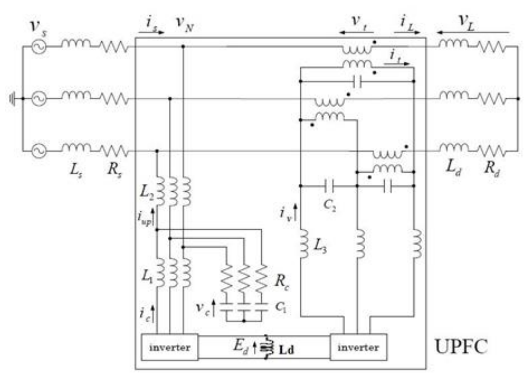

Fig. 1. Structure of UPFC

The Fig. 1 shows the structure of a UPFC which consists of two transformers (an excitation transformer and a boosting transformer), two three -phase GTO based-voltage source converters and a DC link inductor.

UPFC can provide simultaneous, real-time control of all or any combination of the basic power system parameters (transmission voltage, line impedance and phase angle) which is determined by the required transmission power [2]. Shunt converter and series converter of a UPFC can provide shunt compensation and serial compensation for a power system respectively to maintain the bus voltage and modulate power flow of the transmission line.

A. Deadbeat predictive controller

In the proposed methodology, an eminent type of predictive controller is the deadbeat controller. It uses the state space model of the system to calculate reference voltage vector, in order to set the controlled variable error to zero within one sampling time. Next, the referenced voltage vector is realized by modulator. It has been applied for current control in three phase inverters, rectifiers, active filters, power factor correctors, power factor pre-regulators, uninterruptible power supplies, DC-DC converters and torque control of induction machines. This method is being used, when a fast dynamic response is required.

The following characteristics are obtained from the deadbeat response:

- Minimum rise time and settling time
- Zero steady-state error
- Very high control signal output

B. Simulation results

Simulation is performed by PSIM software. The simulation circuit is Fig.1. Circuit parameters of the simulation are listed in Table 1.

Fig. 7 shows result of improvement of power factor by the reactive power compensation and Fig. 8 shows result of the voltage drop compensation when the line voltage decreases. Both of them are in case of the balanced load. Both compensations can be performed properly by the UPFC operation.

The influence in the case of 3-phase unbalance load is inspected. 3-phase unbalance occurs by changing the load resistances. Fig. 8 shows the load current of 3-phase. Fig. 8 shows the line current of 3-phase after the 3-phase unbalanced compensation of the UPFC operation.

The amplitude of 3-phase current becomes equal and the phase is 120 degrees different from each other in Fig. 8, when the 3-phase unbalance compensation can perform in addition to the reactive power compensation by the parallel side of the UPFC.

3. Experimental results

Simulation has become a very powerful tool on the industry application as well as in academics, nowadays. It is now essential for an electrical engineer to understand the concept of simulation and learn its use in various applications. Simulation is one of the best ways to study the system or circuit behavior without damaging it. The tools for doing the simulation in various fields are available in the market for engineering professionals. Many industries are spending a considerable amount of time and money in doing simulation before manufacturing their product. In most of the research and development (R&D) work, the simulation plays a very important role. Without simulation, it is quite impossible to proceed further. It should be noted that in power electronics, computer simulation and a proof of concept hardware prototype in the laboratory are complementary to each other. However, computer simulation must not be considered as a substitute for hardware prototype. The objective of this chapter is to describe the simulation of impedance source inverter with R, R-L and RLE loads using MATLAB tool.

A. The role of simulation in design

Electrical power systems are combinations of electrical circuits and electro-mechanical devices like motors and generators. Engineers working in this discipline are constantly improving the performance of the systems. Requirements for drastically increased efficiency have forced power system designers to use power electronic devices and sophisticated control system concepts that tax traditional analysis tools and techniques. Further complicating the analyst's role is the fact that the system is often so nonlinear that the only way to understand it is through simulation.

Land-based power generation from hydroelectric, steam or other devices is not the only use of power systems. A common attribute of these systems is their use of power electronics and control systems to achieve their performance objectives. Sim Power Systems is a modern design tool that allows scientists and engineers to rapidly and easily build models that simulate power systems. Sim Power Systems uses the Simulink environment, allowing you to build a model using simple click and drag procedures. Not only can you draw the circuit topology rapidly, but your analysis of the circuit can include its interactions with mechanical, thermal, control, and other disciplines. This is possible because all the electrical parts of the simulation interact with the extensive Simulink modeling library. Since Simulink uses MATLAB as its computational engine, designers can also use MATLAB toolboxes and Simulink block sets. Sim Power Systems and Sim Mechanics share a special Physical Modeling block and connection line interface.

B. SIM power systems libraries

You can rapidly put Sim Power Systems to work. The libraries contain models of typical power equipment such as transformers, lines, machines, and power electronics. These models are proven ones coming from textbooks, and their validity is based on the experience of the Power Systems Testing and Simulation Laboratory of Hydro-Québec, a large

North American utility located in Canada, and also on the experience of Ecole de Technologies upérieure and University Laval.

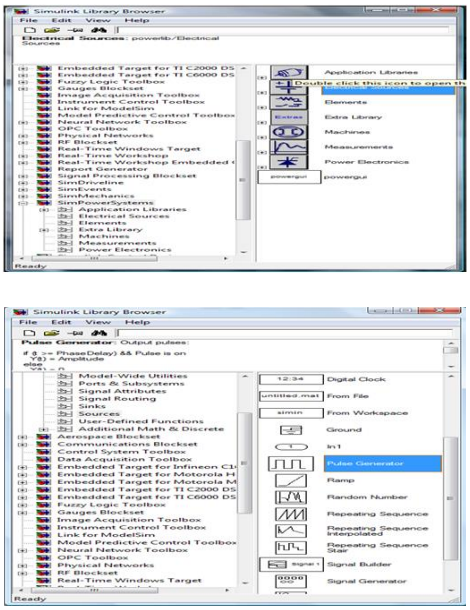

Fig. 2. Matlab library

The capabilities of Sim Power Systems for modeling a typical electrical system are illustrated in demonstration files. And for users who want to refresh their knowledge of power system theory, there are also self-learning case studies. The Sim Power Systems main library, powerlib, organizes its blocks into libraries according to their behavior. The powerlib library window displays the block library icons and names. Double-click a library icon to open the library and access the blocks. The main Sim Power Systems powerlib library window also contains the powergui block that opens a graphical user interface for the steady-state analysis of electrical circuits.

C. Simulation of proposed System

The proposed system is simulated in MATLAB/Simulink Simulation Software. The proposed system is as shown in the Fig. 3.

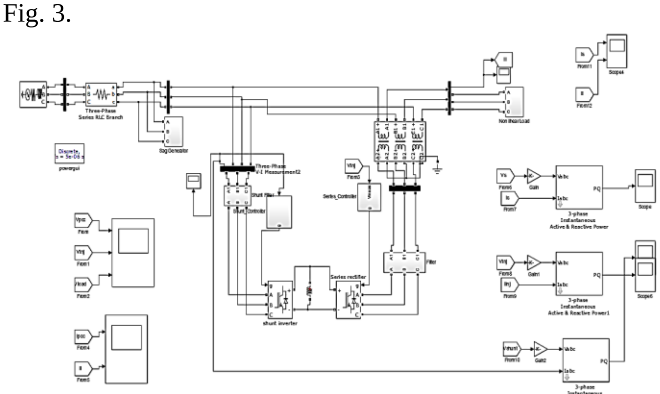

Fig. 3. Simulation diagram of proposed system

The UPFC controller is simulated in the simulation software. The proposed system has sag generation is include in the system to create sag. The proposed control system used deadbeat controller which is used for UPFC controller. It is implemented in both series and parallel compensation. The deadbeat controller is modeled as shown in the Fig. 4.

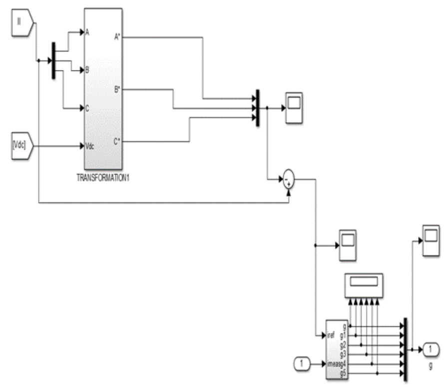

Fig. 4. Deadbeat controller for parallel UPFC controller

The deadbeat controller is also used in series compensation is modeled. The sag generation is as shown in the Fig. 5.

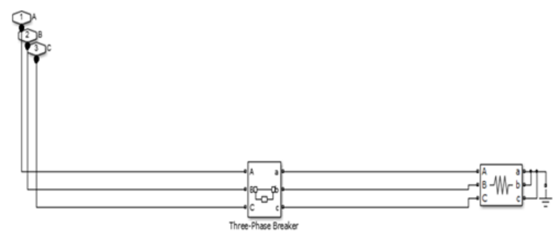

Fig. 5. Sag generation simulation model

The non-linear load connected to the system is modeled as shown in the Fig. 6.

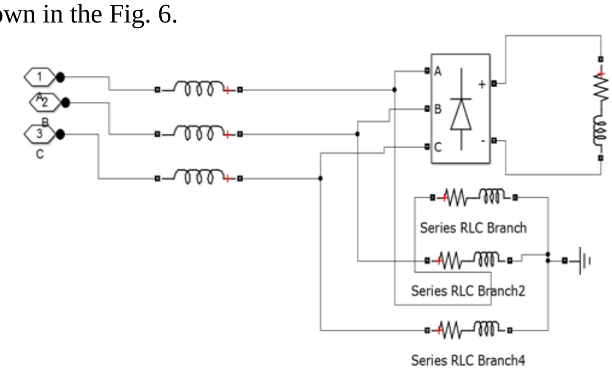

Fig. 6. Non-linear load connected the grid

The system is modeled as shown in the proposed section. The output results are discussed in the next section.

D. Simulation output and results

The simulation is successfully simulated in the MATLAB/Simulink simulation software. The reactive power compensation is a much needed when the non-linear load is introduced in the circuit. The system is of 415 Volt AC.

The transmission line is connected to a nonlinear load, thus a dip in voltage occurs at the point of common coupling.

CASE 1: Without UPFC compensation: The simulation output of voltage at point of common coupling when the sag generation is closed is as shown in the Fig. 7.

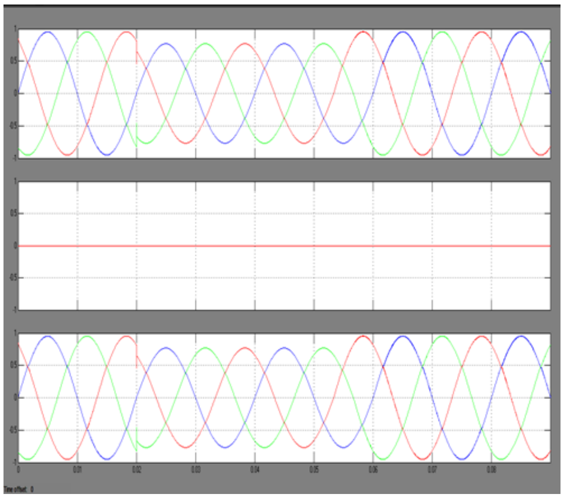
Fig. 7. Voltage at PCC, injection voltage and Load voltage

The voltage sag at the point of common coupling and load voltage is as shown in the Fig. 7. As shown in the figure the voltage injection is zero for generated sag.

CASE 2: Sag Generation Switch Open: For sag output voltage waveform, the compensation device UPFC with proposed controller is added for which the simulation is compiled in MATLAB simulation software. The output voltage waveform of Point of Common Coupling is as shown in the Fig. 8.

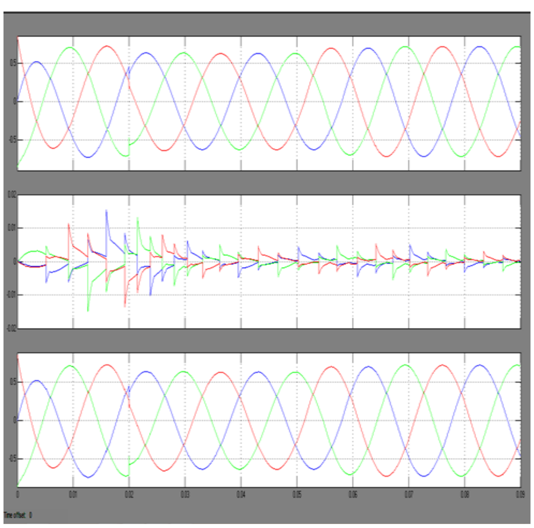
Fig. 8. Voltage at PCC, injection voltage and Load voltage with compensation

The voltage at the PCC and load voltage is enhanced with the proposed converter is as shown in the figure the sag is eliminated.

Table 1
System parameters

Parameters	Value
Nominal System Voltage	300 V
Nominal System Power	0.18 MVA
Sag Voltage Dip	250 V
Real Power Consumption	110 KW
Sag Power Consumption	80 KW
Loss in Power Due to Sag	30 KW
Loss in Voltage Due to Sag	50 V

4. Conclusion

This paper presented the implementation of capacitor less UPFC for power quality improvement using deadbeat controller.

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