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Study of Control Strategies for Unified Power Quality Controller in Grid Power Quality Improvement

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Abstract: *In energy systems, voltage stability has become a critical component. Harmonic currents, poor power factor, supply-voltage changes, and other variables are the main reasons of poor power quality. We must adjust the energy filtering of UPQC in order to get proper operation from it. The universal power conditioner (UPQC) is explored in depth in this work. The UPQC's Mathematical Modeling, fundamental configuration, and control scheme have all been thoroughly covered in this paper. The different backup storage systems used in UPQC are explained, along with a device-specific control mechanism.*

Keywords: UPQC, CSC, power system, linear load.

I. Introduction

The purpose of an electrical energy system is to deliver high-quality power for the proper operation of diverse electrical appliances. However, the widespread usage of non-linear loads in modems energy systems is making them more susceptible to power quality difficulties and contributes to a rise in power quality problems. Harmonic currents, poor power factors, supply-voltage changes, and other difficulties with poor power quality are the most common. Keeping the quality of electrical energy within acceptable standards has always been a difficulty. Poor power quality can lead to increased power losses, anomalous and unwanted device behaviour, and interfering with surrounding communication cables, among other things. In the field of improving electric power quality, the term active power filter (APF) is commonly used. APFs have made it possible to effectively alleviate some of the key power quality issues. The UPQC is a member of the APF family that combines shunt and series APF functionality to achieve improved control over a variety of power quality problems. The role of centralized power quality Supplying voltages flicker/imbalance, power factor, negative-sequence energy, and harmonic are all compensated by the conditioners. The UPQC has the capacity to improve power quality on power system network at the point of construction. The energy conditioner's control method is critical to its performance overall. The core requirements for desired compensating are strong dynamic response of the controllers, rapid detection of disturbance signal with high precision, and processing times of the reference voltage. The control strategy of the UPQC is determined by the generation of an appropriate switching Pattern or gated signals with reference to a commanding compensating signal. Many theories and procedures have been presented or implemented over the years because derivation of reference voltage from measured distortion signals plays such an important role. These might be in either the frequencies or temporal domain. For computing the references values, many variations of the powers theory have been made. Controlling the energy filters of UPQC is required for effective operating.

Unified Power Quality Conditioner (UPQC)

The UPQC stands for unified power quality conditioner. The connecting of series and shunt inverters is the basis for the design configuration. With the current source converter (CSC), the interface is developed is right series and left shunt [1], [2]. UPQC-CSC [3], [4] is designed in this paper, and the outcomes are analyzed. The following features are available in a unified power quality conditioner (UPQC) for nonlinear and voltage sensitivity loads.

(i)It lowers harmonic in the companies are able, resulting in better utility quality level for non - linear loads.

(ii)UPQC meets the load's VAR requirements, ensuring that the supplying current and voltage have always been in phase, obviating the need for extra power factor correction equipment.

(iii)In the face of voltage level sag, UPQC keeps the load end voltage at the rated value.

Figure 1 depicts the UPQC-CSC design setup.

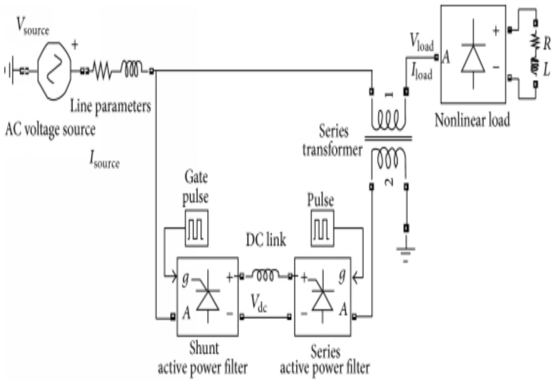

Figure 1: The design configuration of UPQC-CSC

II. Literature review

S. ShamshulHaq et al. [5] This work provides improved control approach performances in UPQC, which boosts the toughness against parameterized power supply and load perturbations as well as the tracking performance of the compensatory reference voltage. To correct for voltage level and supply current distortions, a three phase four wire Unified Power Quality Conditioner (UPQC) with four leg shunt Active Power Filter (APF) is employed in this article.

SoniParth et al. [6] To create the reference signal for voltage and current, researchers used Instantaneous active and reactive power theory (p-q) for shunt active power filters and synchronous reference frame theory (d-q) for series active filters. The system indicates for the shunted voltage source inverter coupled to the sensitivity loading and non-liner load is generated by the control system. The system indicates for the serial voltage source inverter, which is coupled to the feeders thru a series injection transformers, is generated using sinusoidal pulse width modulation techniques (SPWM).

A Sharma et al. [7] For the switching of Series Active Power Filters, a controlling technique based on instantaneous symmetrical component theory (ISCT) is proposed in this study (SEAPF). The SEAPF's series voltage injection effectively manages the load end voltage and protects it from voltage-related issues like sagging, swells, and harmonics. To compensate for real and reactive power, harmonic current, and unbalanced loads, the Shunt Active Power Filter (SHAPF) is managed using balance of power theories.

Aparna B R et al. [8] To compensate for voltage and current defects, a new FACTs (flexible Alternating Current Transmission) circuit dubbed UPQC (universal power quality conditioner) is created in this study. It is controlled using two separate control techniques. The voltage sags and swells are depicted, as well as harmonic currents correction.

BASIC CONFIGURATION OF UPQC

Figure 3 depicts the fundamental configuration of a generic UPQC, which consists of a series actively and shunted active control combinations. Harmonic isolating between such a sub transmission network and a distribution network is the primary goal of the series active filter. At the utility-consumer point of common connection, the series active filter can also compensate for power flicker/imbalance, voltage regulation, and harmonic compensation (PCC).

The shunt actively filter's primary function is to absorb harmonic currents, adjust for power flow and negative sequence current, and manage the dc link voltage between the two active filters.

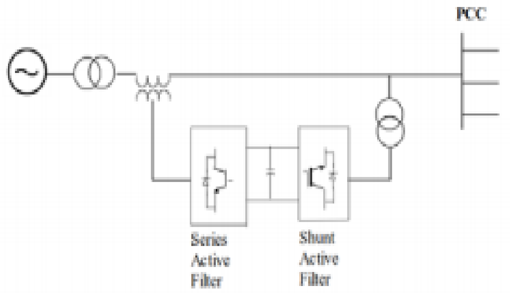

Figure 2: General UPQC

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III. Mathematical Modeling UPQC

The power supply in this study is considered to be a three-phase, three-wire network. The 2 active filtering are made up of two voltage source inverters with three legs each (VSI). The series filter compensates for voltage distortions, but the shunted filters is required to provide reactive power and counterbalance the load's current harmonics injection. The series active power filter also controls the voltage of the DC link capacitance to a desired value. When a power problem happened, the supply may contain negative and zero sequence components. The capacitor bank for the DC link is separated into two groups, each of which is connected in series. Both transformers' secondary neutrals are directly connected to the dc link midway.. As both three-phase transformers are connected Y/Yo, zero sequence voltage arises in the primary winding of the series linked transformers to compensate for the supplying program's negative sequence energy. In the main winding of both transformers, no zero sequencing current to flow. When a power disturbance occurs, it guarantees that the system current is balanced. Assuming a non-linear demand, the energy model of the system can be separated into three parts: the power distribution network, the series active filtering, and the shunt active filter.In this part, the UPQC's constituent members are modelled seperately. In this part, the UPQC's constituent member are modelled seperately. Consider the power generation system firstly. Kirchhoff's law applies.

$$v_{if} = e_i - L_s \frac{di_{is}}{dt} - R_s i_{is} - v_{sh}$$

$$i_{is} = i_{iL} - i_{ih}$$

Where Subscript I denotes the power system's a, b, and c phases; Ls and Rs denote the transmitting line's inductors and resistance; ei denotes the source voltage; vih denotes the series active filter's output voltage; iis denotes the line current; iiL denotes the load current and iis denotes the output current of the shunt active filter, respectively[9].

IV. CONTROL STRATEGIES OF UPQC

Control strategy plays a critical part in improving the system's performance. The UPQC controls strategy can be applied in three steps:

1) Signals of voltage and current are sensed.
2)Compensating commands are developed in terms of voltage or current levels.
3)PWM, hysteresis, or fuzzy logic-based control approaches are used to create gating signals for UPQC semiconductor switches.

The derivation of compensatory instructions in the second step is mostly dependent on two kinds of domain methodologies:

(1) Methods in the frequency response
(2) Method in the time domain

To extract compensatory directives, frequency domain approaches use the Fast Fourier Transform (FFT) of distorted voltage or current inputs. Because of the large calculation, time, and latency, this FFT is not often used. In the time domain, the control methods of UPQC are based on the immediate generation of compensatory commands in the form of voltage or current signals. The following are the two most commonly utilized time domain control mechanisms in UPQC:

1) The p-q theory (instantaneous active and reactive power), 2) The d-q theory (synchronized reference frame approach).

The p-q theory computes instantaneous active and reactive voltages, whereas the d-q theories deals with current that is irrespective of voltage supply.

To separate the fundamental and harmonic values, both approaches transfer voltages and currents from abc frame to stationary reference frame (p-q theory) or continuously rotational frame (d-q theory).

The following are some of the time domain control strategies that have been used:

1) 3phase pq theory or instantaneous active and reactive power
2) 3phase dq theories or synchronized reference frame (SRF)

3) Creation of Unit Vector Templates (UVTG)
4) Control of only one cycle (OCC)
5) Model matched control based on H

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6) Predictive Control Model (MPC)
7) Control of the Deadbeat
8)ANN method (Artificial Neural Network)
9) Theory of feedforward and feedback
10) Linear Multi-Output Adaptive Approach (MOADALINE)

The unit vector template generation (UVTG) approach, a basic controllers scheme for UPQC, uses a phase-locked loop (PLL) to produce unit vector template(s) for single- and three-phase systems.

V. Various Backup Storage Devices Used in UPQC

A. DC storage capacitors

1) Capacitance is used to store energy.
2) It's useful for short trip times.
3) Between the constant power bus and the capacitor, a DC/DC converter is required.
4) As the voyage across time rises, so does the cost.

B. Batteries

1) The most popular technique of energy storage.
2) They don't need a DC/DC converter because they're directly connected to the VSC.
3) Capacitors can compete with battery for short riding times, but only for short periods of time.
4) Use products that are damaging to the environment.
5) Have a finite lifespan.
6) They must be maintained on a regular basis.
7) Some new types of batteries do not have the limits listed above, but they are more expensive.

C. Super Capacitors

1) Energy densities comparable to batteries.
2) Increase the voltage tolerance of the equipment.
3) Have a significantly longer lifespan than battery.
4) They require far less upkeep than batteries.
5) The discharge time must be at least one minute.
6) Capacitors are significantly slower than battery, but they are faster than battery packs.
7) Only a few volts of voltage are available.

D. Flywheels

1) Store energy in fast-spinning flywheels.
2) Stored energy cannot be extracted fully.
3) Require an additional DC/DC converter.

E. Superconducting coils

1) Superconducting magnetic energy storage (SMES) coils are used to store energy.
2) Lowest-cost solutions for high-power, short-duration ride-through application.
3) Energy production is faster than with batteries.
4) When comparison to battery, they are smaller and require little maintenance.
5) Can be installed quickly and easily with short deadlines.
6) They are portable and have a modular design to accommodate future load expansion.
7) Between the SMES and the constant voltage bus, an extra DC/DC converter is required.

VI. ARTIFICIAL INTELLIGENCE

The modeling of human intelligence processes by machines, particularly computer systems, is known as artificial intelligence (AI). Learning (the acquisition of information and the rules for applying it), reasoning (the application of rules to arrive at approximate or definite conclusions), and self-correction are examples of these process. Expert systems, voice recognition, and computer vision are examples of AI applications.

Artificial intelligence can be classified as either stronger or weaker. Weak AI, also known as narrow AI, is a type of artificial intelligence that is developed and taught to do a certain purpose. Strong AI, often known as artificial general intelligence, is a type of artificial intelligence that has human-like intellectual capabilities. When faced with a new task, a powerful AI system can develop a solution without the need for human participation. When these algorithms are combined with the converter's control techniques, the electrical output parameters can be significantly improved.

VII. PROBLEM IDENTIFICATION

The authors investigated several compensatory device control mechanisms in the power system. The use of an optimal control can improve the system's output beyond the results mentioned in the papers, according to a study of several

FACTS techniques. To make it more viable to be connected with the grid, active and reactive power correction must also be done on the grid side. It is possible to investigate the development of a more robust and optimal control algorithms to aid in the improvement of power factor correction in a UPQC modules. This will improve the line's shunt compensation. The research of artificially intelligent controller design, on the other hand, can help achieve even better results and outcomes.

VIII. PROPOSED OBJECTIVE

In addition to capacitor banks, various reactive current supporting devices are employed in electricity grids, and PEC interfaced devices (e.g. UPQC) offer far higher dynamic reactive power compensation capacity than conventional technologies. However, AI-based procedures are now in charge of operating these gadgets, which may be tweaked for further improvement. By studying the harmonic distortion in them, an artificially intelligent control system such as the crow search optimisation algorithm in combo with the traditional method is recommended to improve the output power from of the control method for power compensation as well as performance improvement.

IX. CONCLUSION

The paper looked at a variety of controlling methods as well as the system architecture of the UPQC. According to the results of the literature reviews, these devices, also known as FACTS, play a critical role in maintaining grid stability. In order to create a steady and dependable power system, all grid operators must define reactive power compensation needs for REGs in their grid codes as renewable power penetration levels increase. Modification and integration of the control approaches outlined in the research with artificial intelligence-based optimization algorithms can help improve quality at loaded busses.

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