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Modulation And Control of Transformerless UPFC Using Fuzzy Logic Control

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Abstract *- As per recent need for energy requirement the graph for energy need is increasing at alarm rate. So to bridge the gap between generation and demand is becoming difficult. So considering the fact of energy need the issues and handling problems we come across power quality issues . It is concern as major aspect for sophisticated devices of the power system,whose performance is very sensitive to quality of power supply. Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency,Phase angle that results in a failure of transmission lines.To improve the power quality, custom power devices are used. The device considered in this work is UPFC (unified power ow controller).*

As Unified Power Flow Controller (UPFC) is used to regulate the power flow in the power systems by controlling the various parameters such as impedance, phase angle etc. UPFC offers advantages in terms of static and dynamic operation of the power system. As is well known, the conventional UPFC that consists of two back-to-back inverters requires bulky and often complicated zigzag transformers for isolation and reaching high power rating with desired voltage waveforms.

To overcome this problem, a transformerless UPFC based on Fuzzy control configuration of two cascade multilevel inverters has been proposed. The new UPFC offers several advantages over the traditional technology, such as transformerless, light weight, high efficiency, low cost and fast dynamic response. This proposed system focuses on the modulation and control for this new transformerless UPFC, including optimized fundamental frequency modulation for low total harmonic distortion and high efficiency, independent active and reactive power control over the transmission line, dc-link voltage balance control, etc.The proposed system is designed using simulink in matlab.

Keywords - Flexible ac transmission systems (FACTS), multilevel inverter, power flow control, transformerless, unified power flow controller (UPFC).

I. INTRODUCTION

Simultaneously the control is possible by the unified power flow controller (UPFC), all the parameters which Causes power flow in the transmission line (i.e., voltage magnitude, impedance, and phase angle). The conventional UPFC consists of two back-to-back connected voltage source inverters that share a common dc link, as shown in Fig. 1. The injected series voltage from inverter-2 can be at any angle with respect to the line current, which provides complete flexibility and controllability to control both active and reactive power flows over the transmission line. The resultant real power at inverter-2 is provided or absorbed by inverter-1 through the common dc link. As a result, UPFC is the most powerful flexible and important ac transmission systems device. It can strongly reduce congestions and increase the efficiency of existing transmission lines. This allows the overall system to operate at its maximum capacity. The basic control methods, transient analysis, and practical operation considerations for UPFC have been investigated.

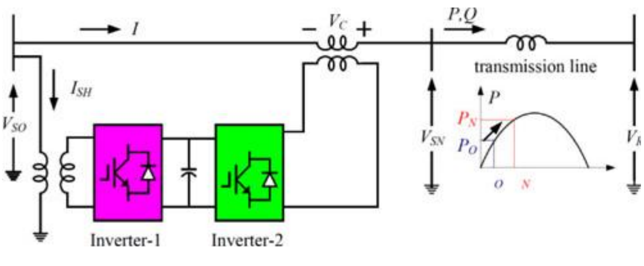

Figure 1. Basic diagram of Conventional UPFC.

Due to the back to back connected inverters the system required the transformer.due to which the system will be bulky and the efficiency of the trnasmission line will be less.

So for this, a new transformerless UPFC based on an new configuration of two CMIs has been proposed. the transformerless UPFC consists of two CMIs, one is series CMI, which is directly connected in series with the transmission line; while the other is shunt CMI, which is connected in parallel to the sending end after series CMI.

The transformerless UPFC has more advantages over the conventional UPFC such as highly modular structure, light weight, high efficiency, high reliability, low cost, and a fast dynamic response. This paper presents the modulation and control for the new transformerless UPFC to address aforementioned challenges using the fuzzy logic control. The UPFC functionality with proposed control method is verified at low voltage level an both the steady-state and dynamic responses results.

II. OPERATION OF TRANSFORMERLESS UPFC

With the unique construction of the series and shunt CMIs, the transformerless UPFC has some other new features:

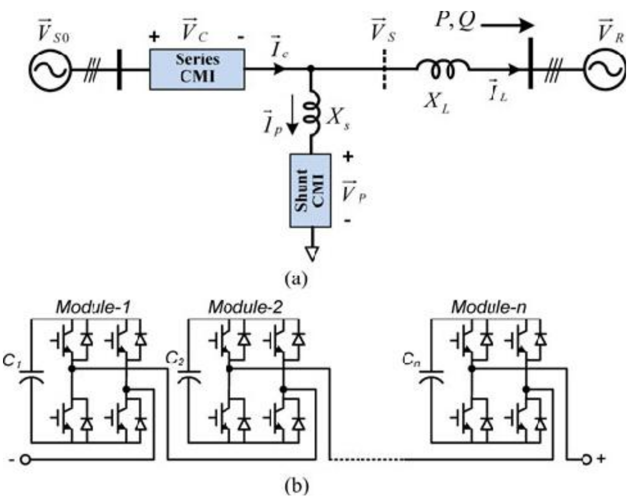

Figure 2. New transformerless UPFC. (a) System configuration of transformerless UPFC. (b) One phase of the cascaded multilevel inverter.

1) Not the conventional back-to-back dc link coupling, the transformerless UPFC requires no transformer, thus it can get low cost, light weight, small size, high efficiency, high reliability, and fast dynamic response. 2) The shunt inverter is connected after the series inverter, which is outlined different from the conventional UPFC. Each CMI has dc capacitor to support dc voltage. 3) There is no active power exchange between the two CMIs and all dc capacitors are floating. 4)The new UPFC uses modular CMIs and their integral configuration provides greater flexibility and higher reliability.

Due to the specific system configuration, the primary operation principle of the transformerless UPFC is quite different from conventional UPFC. Fig. 3 shows the phasor diagram of the transformerless UPFC, where Vso and VR are the original sending end and receiving end voltage, respectively. Here,Vso is allied with real axis, which means phase angle of Vso is zero. The series CMI is controlled to generate a desired voltage Vc for obtaining the new sending end voltage Vs, which in turn, controls active and reactive power flows over the transmission line. Meanwhile, the shunt CMI injects a current Ip to the new sending-end bus to make zero active power into both CMIs, i.e., to make the series CMI current Ic and the shunt CMI current Ip be perpendicular to their voltages Vc and Vs, respectively. As a result, both series and shunt CMIs only need to provide the reactive power. In such a way, it is possible to apply the CMIs to the transformerless UPFC with floating dc capacitors for H-bridge modules.

A. Fundamental Frequency Modulation (FFM) For CMIs

Before start on development of UPFC control, the modulation method for CMIs is introduced first. In general, the modulation for CMIs can be categorized into two main categories:

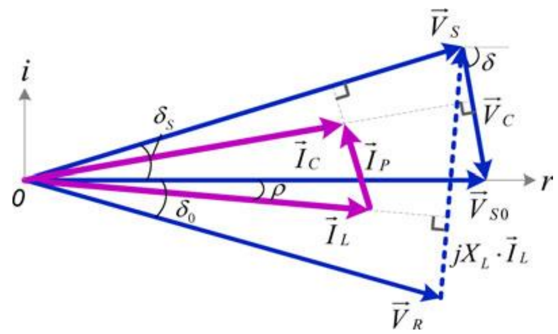

Figure 3. Phasor diagram of the transformerless UPFC.

1) FFM and 2) Pulse width modulation (PWM). Compared to the PWM, the FFM has lower switching loss, making it powerfull for the transmission-level UPFC and other high-voltage high-power applications. The FFM has been analyse for many years, however, most studies centralised on the FFM optimization with low number of modules

(e.g., four to five) and the steady-state THD minimization. In this paper, FFM will be designed with high number of modules. Generally, switching angles will be optimized for all ten series H-bridge modules and 20 shunt H bridge modules to attain extremely low THD. Furthermore, it will also demonstrate that CMIs with FFM can also attain fast dynamic response, e.g., 8 ms.

B. Optimization of Switching Angles for Minimum THD

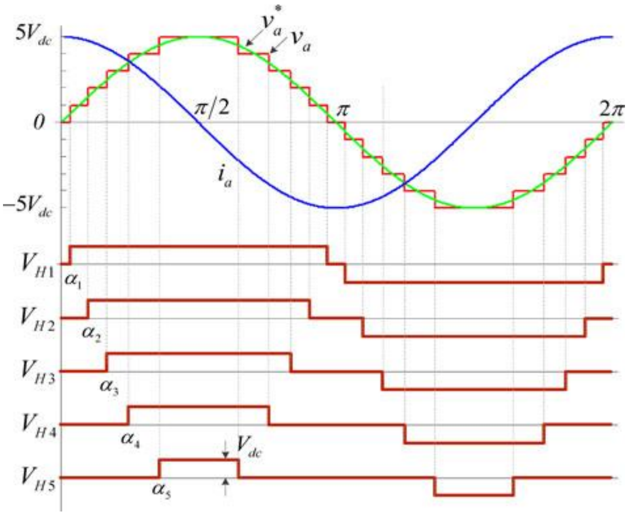

Figure 4: Operation principle of FFM.

Fig. 4 shows the operation principle of conventional FFM, where phase *a* output voltage of an 11-level CMI is shown as an example. A stair-case voltage waveform, V_a could be compound when each of five H-bridge modules generates a quasi-square wave, V_{H1}, V_{H2},...,V_{H5}. Each H-bridge has the same dc link voltage V_{dc} for the modular design consideration. Different conceptualisation have been studied in to decide the switching angles of H-bridge modules for selected harmonic minimum THD. However, these papers mostly centred on low number (less than five) of H-bridge modules. Here, switches angles will be optimized for minimum THD with the high number of H-bridge modules for the transformerless UPFC.

C. Analysis of Capacitor Charge of H-Bridges

Capacitor charge of H-bridges will be designed based on two layers: 1) first layer is overall capacitor charge, meaning the total capacitor charge of all H-bridges of any one of three phases; 2) the other layer is individual capacitor charge, meaning the capacitor charge of each H-bridge. In preceding analysis, the CMI output voltage is predicted to lead or lag the output current by 90°, to attain zero active power flow from ac side into dc capacitors.

FFM with total 20 H-bridges. (a)Output voltage and current (41 levels) and (b) output voltage of each H-bridge.

III. POWER FLOW AND DC-LINK VOLTAGE CONTROL OF TRANSFORMERLESS UPFC:

It is desirable to design a control system, which can severally regulate the active power P and reactive Q in the line, at the same time, maintain the capacitor voltages of both CMIs at the given value. Fig. 6 shows the overall control system, which is divided into three stages, i.e., stage I to stage III.

Stage I: The calculation from P*/Q* to V_{co}^* and I_{p0} As mentioned before, the Vco is the voltage reference for series CMI, which is generated according to the transmission line power command, while Ipo is current reference for shunt CMI, which is used to keep zero active power for both CMIs. Note that instead of calculating Vco directly.

Stage II: Overall dc-link voltage regulation. With the Vco and Ipo given in stage I, the dc-link voltage cannot be maintained due to the following three main reasons: 1) the CMIs always have a power loss, 2) the calculation error caused by the parameter deviations, 3) the error between reference and actual output. In order to control dc-link voltage with better robustness, two variables ΔVc and ΔIP were introduced for the independent dc-link voltage regulation of series CMI and shunt CMI, respectively. For the series CMI, Pse is the output of overall dc-link voltage regulation loop, Rse is then calculated by dividing Pse by I2C (square of rms value of series CMI current), finally ΔVC is the product of Rse and series CMI current IC . Obviously, the introduced ΔVC is always in phase with series CMI IC , which can be regarded as active-voltage component. Basically, Rse is the equivalent resistance of series CMI, and the dc-link can be balanced when Pse is equal to Ploss (total power loss of series CMI). For the shunt CMI, ΔIP is introduced for the dc-link voltage control in a similar way.

Stage III: Voltage and current generation for series and shunt CMI, respectively. For series CMI, output voltage could be directly generated from the reference Vc by FFM. While for shunt CMI,

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decoupling feedback current control is used to control output current to follow the reference current Ip.

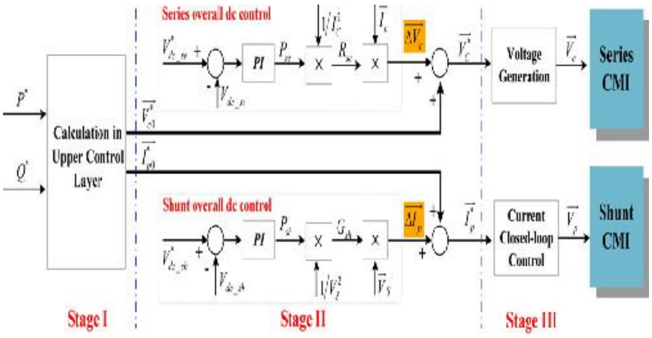


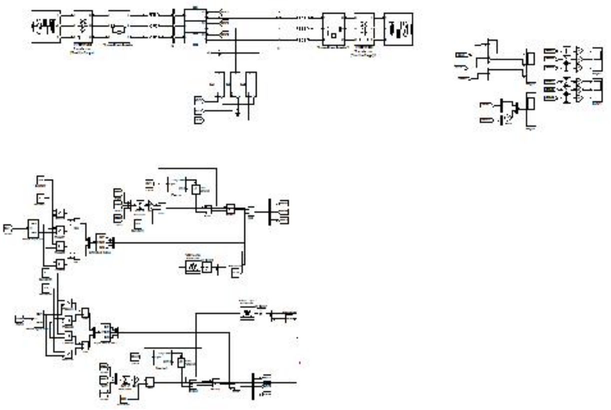
Figure 5: Control system for transformerless UPFC Overall control diagram for both power flow and dc capacitor voltage control.

By using the PI control strategy for the modulation and control of transformerless UPFC the time required to generate the pulses is more.so the dynamic response using PI controller is also is very low.

So in this paper the fuzzy control strategy is used for the controlling purpose.so their is no need of time constant and the dynamic respose of the system is more as compared to the PI controller.

Fuzzy logic is the membership function which automatically analized the system gives outpt as early as possible.

The simulation diagram using fuzzy logic control:



IV EXPERIMENTAL RESULTS

Some different cases are there for which the the different experimental results are as follows

A. UPFC Operation - Phase Shifting

Case A1 to A2:

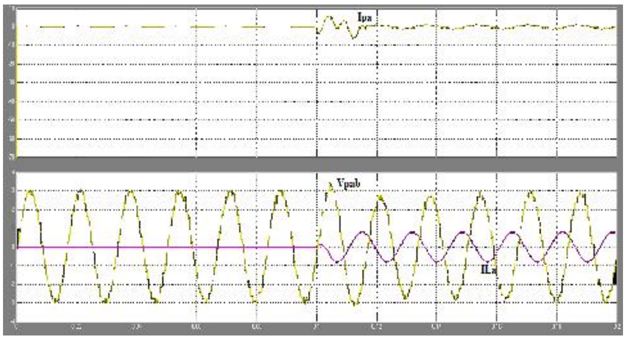


Fig. 6 Experimental waveforms of UPFC operating from case A1 to case A2

Case A2 to A3:

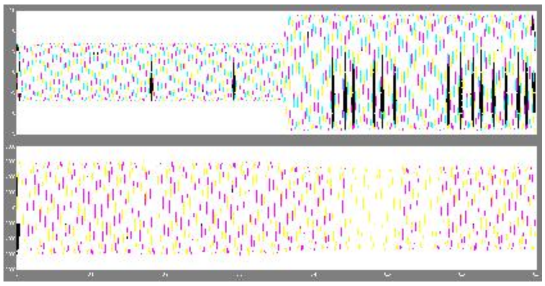
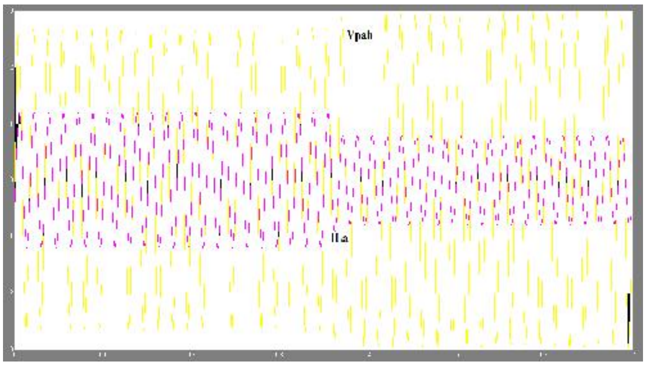


Fig.7. Measured dynamic response with operating point changing from case A2 to case A3

B.UPFC Operation LineImpedance Compensation:

Case B1 to B2



VI. CONCLUSION

A modulation and control method for the transformerless UPFC, which has the following advantages: 1) FFM of the CMI for extremely low THD of output voltage, low switching loss and high efficiency, 2) All UPFC functions, such as voltage regulation, line impedance compensation, phase shifting or simultaneous control of voltage, impedance, and phase angle, thus achieving independent active and reactive power flow control over the transmission line; 3) Dc capacitor voltage

balancing control for both series and shunt CMIs; 4) Fast dynamic response (<10 ms). The transformerless UPFC with proposed modulation and control can be installed anywhere in the grid to maximize/optimize energy transmission over the existing grids, reduce transmission congestion and enable high penetration of renewable energy sources.

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