A Critical Study on the Role of Unified Power Flow Control in Voltage Power Transfer

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Abstract- **The unified power flow controller (UNIFIED POWER FLOW CONTROL) is being used as a compensating and power control device in the power systems due to its easy build, high robustness and efficiency. Simulation results reveal that as far as voltage sag and swell are concerned both the two-level and five level inverter based UNIFIED POWER FLOW CONTROL exhibit the similar performance.As the five level inverter based UNIFIED POWER FLOW CONTROL generates nearly sinusoidal load voltage, its THD is observed to be 3.15%. It is 15.65% in the case of its two level counterparts. It may be noted that for power of good quality the THD must be less than or equal to 5% as per standards. Hence, with respect to power quality, the five level UNIFIED POWER FLOW CONTROL scheme has an edge over two level UNIFIED POWER FLOW CONTROL scheme.**

I. INTRODUCTION

Fewer natural resources and ever increasing demand has set the stage for unprecedented changes and new regulations. In this restructured and deregulated power system environment, added problem is restriction building new transmission lines and generating plants. Therefore the thrust has shifted to maximize available transmission facilities. Unregulated active and reactive power flows may result in loss of power system stability, high transmission losses, voltage collapse etc. Power flow generally in the low impedance path, there by overloading that line and restricting UPFC with minimum losses and low storage capacity at unity or higher voltage transfer ratio. This research work proposes a unique converter structure using Z Source Impedance coupled to Bridge Configured Matrix Converter based unified power flow controller not dealt with so far

The UPFC is capable of integrating all conventional transmission control concepts i.e. series compensation, phase shifting, and voltage regulation into a generalized power flow controller. As a dynamic real and reactive power flow controller with operations under power system oscillations and transmission line faults it is competent of enhance the transfer capability of the transmission line beyond imagination.

Extensive researches continue to contribute on different structures and converter configurations of UPFC. The conventional VSC based unified power flow controller, has the internal loss of extensive direct current network capacitor striking further destruction and the model proponent placed unified power flow controller has the disadvantage of less current(volt.) variation proportion. The controllable parameters of unified power flow controller and the system state variables are certainly adjusted to obtain a UPFC. Voltage collapse normally occurs in heavily loaded and faulted lines.

Detailed investigations on steady state voltage stability analysis like PV curve, Stability Indices, VQ curve and Modal analysis are made on different IEEE test bus systems to identify critical nodes and voltage control areas before the placement of UPFC. A comparison of results obtained with and without PIM- UPFC in voltage stability analysis is discussed. Thus optimal reactive power compensation becomes a necessity with minimum transmission losses, best location for the reactive compensation device in addition to its rating, enhanced voltage at all nodes level and improved voltage stability margin. Therefore this problem can be designated as highly nonlinear, multimodal, and discontinuous i.e. a combinatorial optimization problem. Evolutionary based Genetic Algorithm is adopted to provide an optimal power flow solution.

II. LITERATURE REVIEW

In all electric power transmission system, whether overhead lines or underground cables, there will be a drop of voltage along the system when current flows in it. This drop will vary with the current and power factor.

The variations in voltage are permissible, but with favorable zones, for example the rise or drop in voltage should not exceed a prescribed tolerance of ± 10% of the nominal voltage.

Yanfang Wei et al., (2011)[15]uses the MATLAB Voltage StabilityToolbox to study power flow, singularity based analysis, eigenvalue analysis, static and dynamic bifurcation analysis and time domain simulation.

(Sharad*et. al.* 2010)[5](Yan Zhang and Jovica V. Milanovic 2010) presents an approach to optimally select and allocate flexible ac transmission (FACTS) devices in a distribution network in order to minimize the number of voltage sags at network buses. Three types of FACTS devices are implemented in this study, namely, static var compensator, static compensator, and dynamic voltage restorer.

 ISBN: 978-93-5288-448-3

Naidu and Fernandes (2009[14])decribed the closed loop control of a four leg VSC based DVR. The three phase input variables are resolved into positive, negative and zero sequence components using a weighted, recursive, least square estimator. A laboratory model of the restorer has been constructed and its performance has been tested by simulation using MATLAB and experiments.

Sasitharan and Mahesh K. Mishra (2009)[4] proposed a filter structure for improving the performance of switching band controller based DVR. The control method of the VSI inherits merits, Such as fast dynamic response, robustness, zero magnitude/phase errors and ease of implementation. The proposed filter structure and the adaptive band controller for the DVR are presented by carrying out PSCAD simulation studies.

The design strategy for optimizing the total rating of an IDVR is presented **(Karshenas and Moradlou 2008)[13].** An IDVR, which is two DVRs installed in two feeders with a common DC bus, has the ability of active power exchange between two DVRs, and thus the energy storage device is not an issue. Therefore, the design criteria for the selection of the rating of an individual DVR is not applicable to the IDVR obtained.

Bingsen Wang *et. al.* (2006)[1] described the detailed design of a closer loop regulator to maintain the load voltage within acceptable levels in a DVR using a transformer coupled H bridge converters. A laboratory scale experimental prototype was developed tha verifies the power circuit operation and controller performance. The experimental results indicate an excellence with the digital simulations.

MahindaVilathgamuwa*et. al.* (2006)[2] proposed a new topology based on the Z source inverter for the DVR, in order to enhance the voltage restoration property of the device. It was observed that the DVR compensates the disturbance caused by a sag effectively, while utilizing the stored energy fully by the use of the buck – boost capability of the proposed Z source inverter.

Poh Chiang Loh*et. al.* (2004)[6] described a detailed analysis on Z source inverter modulation, showing how various conventional PWM strategies for controlling a conventional VSI can be modified to switch a voltage type Z source inverter either continuously or discontinuously. The theoretical and modulation concepts presented have been verified both in simulation and experimentally.

III. UNIFIED POWER FLOW CONTROL SYSTEM

The control algorithm are classified as open and closed loop system.

The control algorithm of **open loop system** is based on the active power filter reference current calculation method. In the UNIFIED POWER FLOW CONTROL system without shunt compensation, the line current consists of active and reactive components (neglecting the dc and harmonic components) as in Equation (3.1).

$$\overrightarrow{\iota(t)} = \overrightarrow{\iota_p(t)} + \overrightarrow{\iota_q(t)} = I_p\, sin(\omega t) + I_p\, cos(\omega t)$$

Where,

$i_p(t)$- in phase line active current of the transmission line

$i_q(t)$- reactive current of the transmission line

To regulate the voltage at bus connected to the shunt converter of the UNIFIED POWER FLOW CONTROL, the only component that this bus should supply is the active current component. Using Equation (3.1), it can be noted that if the shunt converter of the UNIFIED POWER FLOW CONTROL supplies the reactive component, then the sending bus needs only to supply the active component. This can easily accomplished by subtracting the active current component from the measured line current.

$$\iota_q(t) = \iota(t) - I_p\, sin(\omega t)$$

In Equation (3.2), I_p is the magnitude of the in-phase current (to be estimated) and sin(ωt) is a sinusoid in phase with the line voltage. The circuit shown in Figure 3.1 can accomplish this operation.

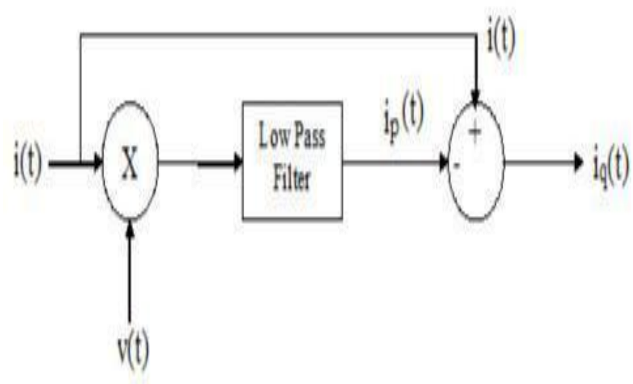

Figure 3.1Open-loop system for calculating the UNIFIED POWER FLOW CONTROL shunt injected current)

$$i(t).\, sin(\omega t) = \frac{p}{2}[1 - cos(2\omega t)] + \frac{q}{2} sin(2\omega t)$$

After the multiplication, the only dc term in Eqn. (3.3) is proportional to I_p. Thus, a low-pass filter whose cut off frequency is below ω permits to obtain I_p which is an estimation of the magnitude of $i_p(t)$. Then, this dc value is multiplied by the same in-phase sinusoid, obtaining an estimation of the instantaneous active current $i_p(t)$. Finally, this value of $i_p(t)$ is subtracted from the measured line current obtaining the reactive current $i_q(t)$ injected to the power system.

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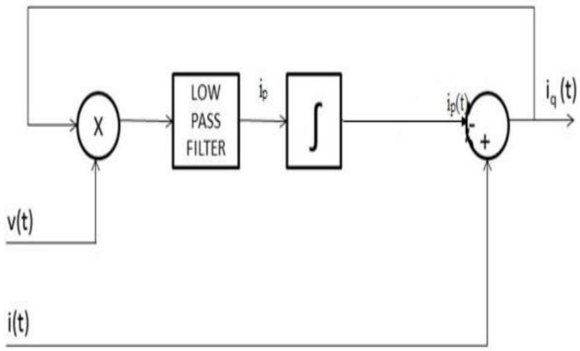
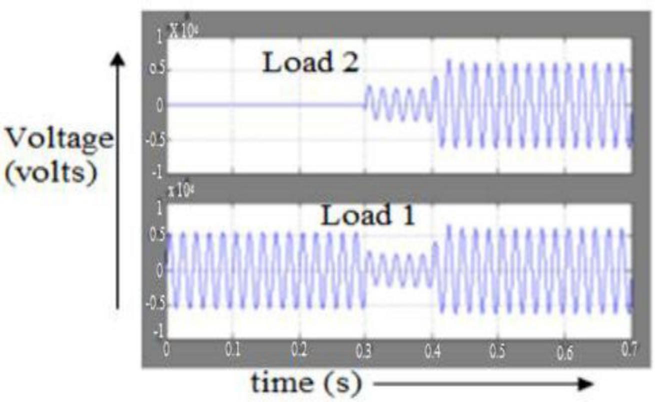


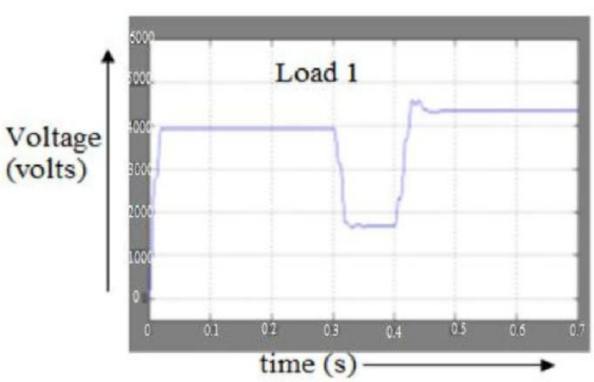
Figure 3.2 Closed-loop modified systems for UNIFIED POWER FLOW CONTROL shunt injected current

The Figure 3.2 shows the closed loop control algorithm for the UNIFIED POWER FLOW CONTROL system. The reactive component of the current $i_q(t)$ is multiplied with instantaneous voltage v(t) and the resultant is passed through the low pass filter to get i_p. The output of low pass filter is integrated with an integral constant, so as to get $i_p(t)$. The difference of the real component $i_p(t)$ and instantaneous current i(t) gives the resultant reactive component $i_q(t)$ required for the UNIFIED POWER FLOW CONTROL system, to inject the shunt current.

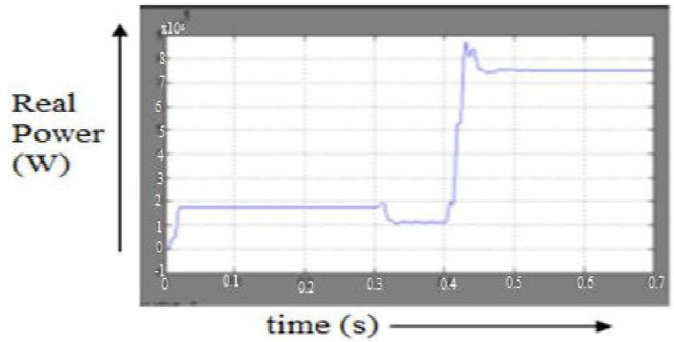
IV. RESULTS



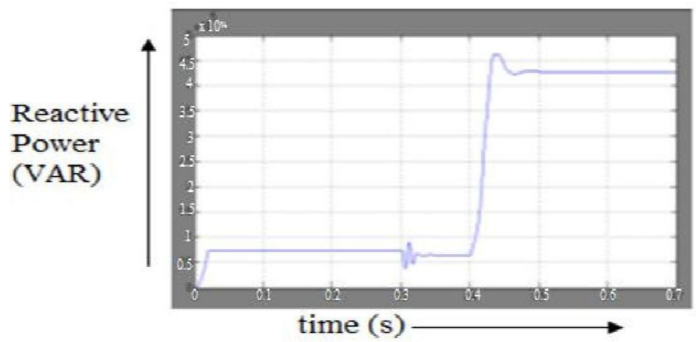
(a) Voltage across Load -2 and Load 1



(b) RMS voltage of Load -1



(c) Real Power



(d) Reactive Power

Figure 3.9 Simulated Results of Compensated System

V. CONCLUSION AND FUTURE SCOPE

Performance comparison has been made between uncompensated and compensated two bus system on the aspects of voltage sag, swell, load voltage, real power, reactive power and THD. It may be noted that the compensated system refers to the power system controlled by UNIFIED POWER FLOW CONTROL. The UNIFIED POWER FLOW CONTROL built with open-loop two level rectifier inverter has been used in this case.From simulated results, the sag is found to be 40% of the system voltage the additional load of (25+j50) ohm theconnected with the uncompensated system. In the case of compensated system, the sag is only 18.5% and its duration is just 0.1sec. Compensated system exhibits improved real power flow and reduction in reactive power supplied by the source unlike uncompensated system.in firing angle of the UNIFIED POWER FLOW CONTROL decreases the load voltage. Performance analysis of UNIFIED POWER FLOW CONTROL based power systems can be made using modern controllers viz., fuzzy tuned controllers, Adaptive Neuro fuzzy controllers and controllers driven by soft computing

The voltage swell is observed as 1.25 times the supply Voltage in the uncompensated system whereas it is just 10% higher than the supply voltage with the compensated system and it lasts only for 0.1sec.

 ISBN: 978-93-5288-448-3

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 ISBN: 978-93-5288-448-3