ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 2, Issue 1, January 2014

Dynamic Reactive Power Control of Islanded Microgrid Using IPFC

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Abstract: This paper discusses the dynamic behavior of flexible ac transmission system devices such as Interline Power-Flow Controller (IPFC). The interline power flow controller (IPFC) proposed is a new concept for the compensation and effective power flow management of multi-line transmission systems. The advantage of this method is that it can avoid unstable voltage conditions in micro grid by prediction of the instability ahead of time. This method can also avoid voltage drops or swells in any of the phases of the system. This capability makes it possible to equalize both real and reactive power flow between the lines, transfer power from overloaded to under loaded lines, compensate against reactive voltage drops and the corresponding reactive line power and to increase the effectiveness of the compensating system against dynamic disturbances. The method is used for control action compare to other Voltage and Var Control (VVC) method.

Keywords: Interline Power Flow Controller (IPFC), Reactive Power Control, Power System Dynamics, MicroGrid.

I. INTRODUCTION

The technology of power system utilities around the world has rapidly evolved with considerable changes in the technology along with improvements in power system structures and operation. The ongoing expansions and growth in the technology, demand a more optimal and profitable operation of a power system with respect to generation, transmission and distribution systems [8]. In the present scenario, most of the power systems in the developing countries with large interconnected networks share the generation reserves to increase the reliability of the power system. DG systems all support the proliferation of DG units in electric utility systems [4]. However, the increasing complexities of large interconnected networks had fluctuations in reliability of power supply, which resulted in system instability, difficult to control the power flow and security problems that resulted large number blackouts in different parts of the world [7]. The reasons behind the above fault sequences may be due to the systematical errors in planning and operation, weak interconnection of the power system, lack of maintenance or due to overload of the network.

In order to overcome these consequences and to provide the desired power flow along with system stability and reliability, installations of new transmission lines are required. However, installation of new transmission lines with the large interconnected power system are limited to some of the factors like economic cost, environment related issues [1]. These complexities in installing new transmission lines in a power system challenges the power engineers to research on the ways to increase the power flow with the existing transmission line without reduction in system stability and security. Reactive power control of Microgrids integrating a wind and photovoltaic source has many technical challenges [1].This technology of power electronic devices is termed as fl Flexible Alternating Current Transmission Systems (FACTS) technology. The use of local signals as feedback to control the converters is desirable, since in a real system, the distance between the converters may make an inter-communication impractical [2]. It provides the ability to increase the controllability and to improve the transmission system operation in terms of power flow, stability limits with advanced control technologies in the existing power systems [8],[10]-14]. The main objective to introduce FACTS Technology is as follows:

- To increase the power transfer capability of a transmission network in a power system.
- To provide the direct control of power flow over designated transmission routes.

- To provide secure loading of a transmission lines near the thermal limits.To improve the damping of oscillations as this can threaten security or limit usage line capacity.

II. REACTIVE POWER

Reactive power is the form of magnetic energy flowing per unit time in an electric circuit. Its unit is VAR (Volt Ampere Reactive). This power can never be used in an AC circuit. However, in a DC circuit it can be converted into heat as when a charged capacitor or inductor is connected across a resistor, the energy stored in the element get converted to heat. Our power system operates on AC system and most of the loads used in our daily life are inductive or capacitive, therefore reactive power is a very important concept from electrical perspective [7]. The electrical power factor of any equipment determines the amount of reactive power it requires. It is the ratio of real or true power to the total apparent power required by an electrical appliance.

Apparent Power (S) = V (Voltage) * I (Current) (1)

Reactive Power (Q) = V (Voltage) * I (Current) * sin θ (2)

Real Power (P) = V (Voltage) * I (Current) * cos θ (3)

Where θ is the phase difference between voltage and current and cosθ is power factor of the load. Reactive power is always present in a circuit where there is a phase difference between voltage and current in that circuit such as all our domestic loads are inductive. So, there is a phase difference between voltage and current, and the current lags behind the voltage by certain angle in time domain (1),(2). An inductive component takes the lagging reactive power and a capacitive component absorbs the leading reactive power, here lagging reactive power refers to magnetic energy and leading reactive power refers to electrostatic energy.

A. Reactive Power Control

Voltage changes continuously according to the varying electrical demand, transmission lines utilization, system control by the control centers, and emergency situations occurred in the system. Since customers require voltage quality, at delivery points, to meet the agreed criteria, it is the control centers' responsibility to control the voltage so that it can satisfy the agreement. Controlling the voltage is regional problems. In other words, the voltage controlling problems are needed to be solved separately by each control area.

B. Dynamic Reactive Power Control

The transmission of electrical energy using AC started at the end of the 19th century and replaced smaller existing local DC distribution systems. By extending local supply areas and providing energy transfer over longer distances various problems regarding mainly voltage control and stability were observed caused mainly by reactive power unbalances in the systems. Switched reactive power compensation (shunt capacitors, shunt reactors) were primarily used to control the steady state system voltages. Dynamic reactive compensation was based on rotating machines, eg synchronous condensors. Fast response times, lower losses and less maintenance requirements of thyristor controlled devices resolved the limitations of rotating machines and DC controlled devices.

C. Islanded Microgrids

Islanded operating condition, the microgrid has to maintain the power balance independently of a main grid. Because of the specific characteristics of the microgrid, such as the resistive lines and the high degree of power-electronically interfaced generators, new power control methods for the generators have been introduced. For the active power control in this paper, a variant of the conventional droop P/f control strategy is used, namely the voltage-droop controller. However, because of the small size of the microgrid and the high share of renewable with an intermittent character, new means of flexibility in power balancing are required to ensure stable operation. Therefore, a novel active load control strategy is presented in this paper. The aim is to render a proof of concept for this control strategy in an islanded microgrid. The active load control is triggered by the microgrid voltage level.

The latter is enabled by using the voltage-droop control strategy and its specific properties. It is concluded that the combination of the voltage-droop control strategy with the presented demand dispatch allows reliable power supply without inter unit communication for the primary control, leads to a more efficient usage of the renewable energy and can even lead to an increased share of renewable in the islanded microgrid.

D. Dynamic Reactive Power Control Of Islanded Microgrids

Reactive power control is a fundamental issue in microgrids, especially during islanded mode operation with no support from the main grid. Lack of infinite bus, tightly coupled generation and consumption, and existence of non dispatchable intermittent renewable power sources reinforce the need for a new VVC scheme. This paper presents a new model predictive control (MPC)-based dynamic voltage and var control (VVC) scheme, which includes the dynamics of the microgrid in the VVC formulation.

The MPC-based controller uses a simplified voltage prediction model to predict the voltage behavior of the system for a time horizon ahead. The advantage of this method is that it can avoid unstable voltage conditions in microgrids by prediction of the instability ahead of time. This method can also avoid voltage drops or swells in any of the phases of the system since the model can predict the voltage of each phase separately. Also, the presented method can be implemented online so it can efficiently use the time-variant reactive capabilities of the distributed generators to compensate for reactive power needs of the system. This controller is tested for different operating conditions of the microgrid and the simulation results confirm that the MPC controller successfully keeps the system stable and achieves a smooth voltage profile.

III. INTERLINE POWER FLOW CONTROL

The IPFC is able to carry out an overall real and reactive power compensation of the total transmission system This capability makes it possible to equalize both real and reactive power flow between the lines, transfer power from overloaded to under loaded lines, compensate against reactive voltage drops and the corresponding reactive line power, and to increase the effectiveness of the compensating system against dynamic disturbances. The paper explains the basic theory and operating characteristics of the IPFC with pharos diagrams, P-Q plots and simulated waveforms. The interline power flow controller (IPFC) is one of the latest generation flexible AC transmission systems (FACTS) controller used to control power flows of multiple transmission lines. This paper presents a mathematical model of IPFC, termed as power. Interline power flow Controller (IPFC) is one of the newest FACTS (Flexible AC Transmission Systems) devices.

This controller can simultaneously control power flow of multiple lines. In this paper IPFC converters are considered as hypothesis bus in the power flow equations and then are matched with the Newton power flow, a program in MATLAB has been written order to extend conventional NR algorithm based on this model. A case study is conducted on 6-bus & 3-machine and 30-bus & 6-machine systems, and the results are examined in the absence and presence of IPFC in the network

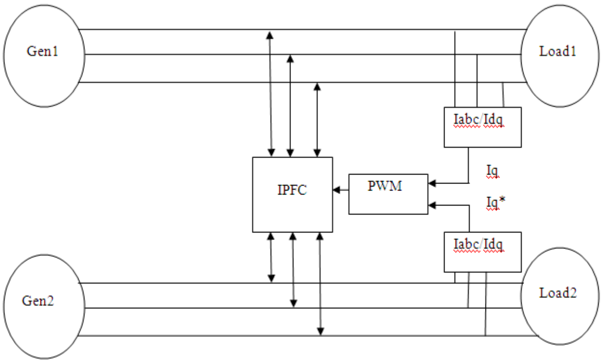

Fig.1.Block diagram of Damping Performance Analysis of IPFC Using Validated Small-Signal Models

This represented with two VSC in the case study. The numerical results of this study show the capability of this tool in controlling the power flow in power system. The IPFC controller is implemented between two power transmission lines. The vector control method is used to control the IPFC converter. This control provides the better control over the control of active and reactive power flow in the transmission lines. The FACTS devices are planned for power flow regulation and their additional degrees of freedom act as additional potential in optimizing the power system. The performance of the UPFC and the IPFC is compared from the viewpoint of the total active power losses and their necessary capacities through numerical examples. The feasibility of a gradient-based algorithm, namely sequential quadratic programming (SQP), is tested, and the importance and some techniques of proper selection of the initial optimization conditions are also presented.

IV. SIMULATION RESULTS

The grid-side converter is designed to be able to inject reactive power back to the grid. The diesel generator acts as the master generator and regulates the system frequency in islanded mode. The control input to the system are the reference voltage of the synchronous diesel master generator, reactive power set points of the distributed generator and the status of switched capacitor banks .The optimal inputs to reduce the effect of load change in the system The diesel generator acts as the master generator and regulates the system frequency in islanded mode. The optimal control sequence achieved from solving the optimization problem was sent to the sources and the compensators of the microgrid.

The performance of the proposed concept by using IPFC has been evaluated by using Matlab/Simulink environment.

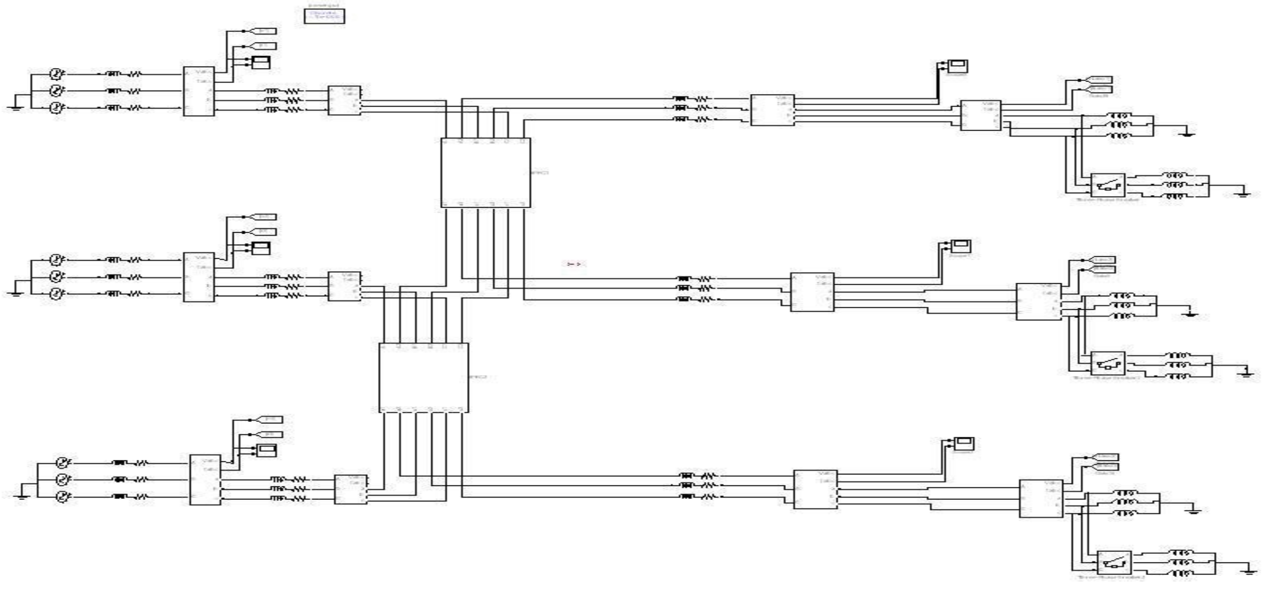

Fig.2.Simulation Diagram for Dynamic Reactive Power control of Islanded Microgrid using IPFC

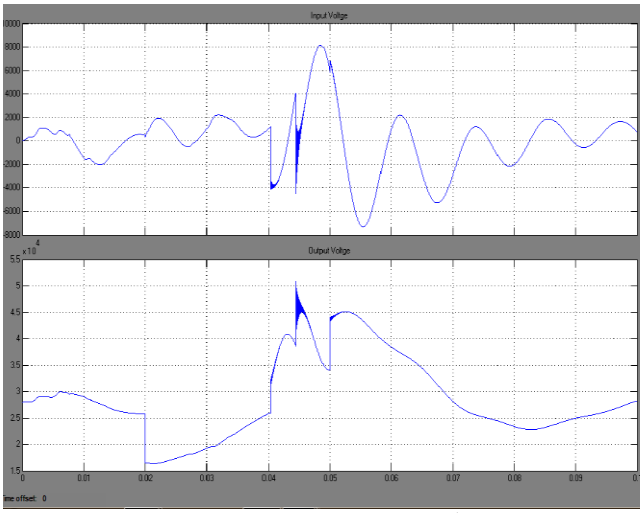

Fig.3. Real and Reactive power control of IPFC1

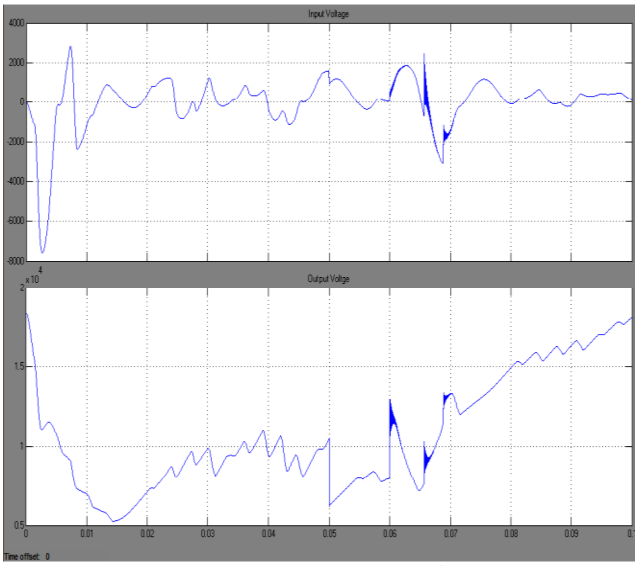

Fig.4. Real and Reactive power control of IPFC 2&3

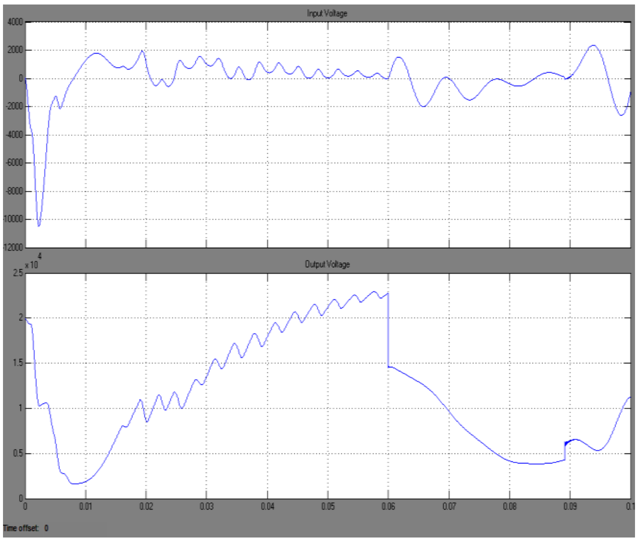

Fig.5.Real and Reactive power control of IPFC 3&1

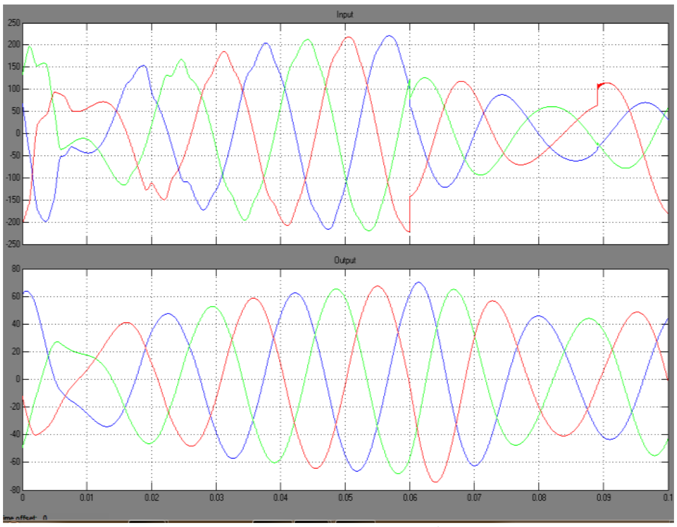

Fig.6. Voltage and Current Control of IPFC 1

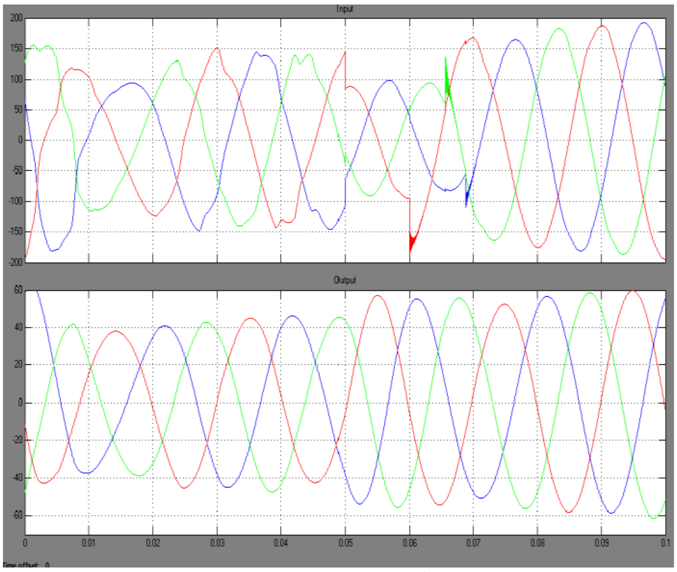

Fig.7. Voltage and Current Control of IPFC 2&3

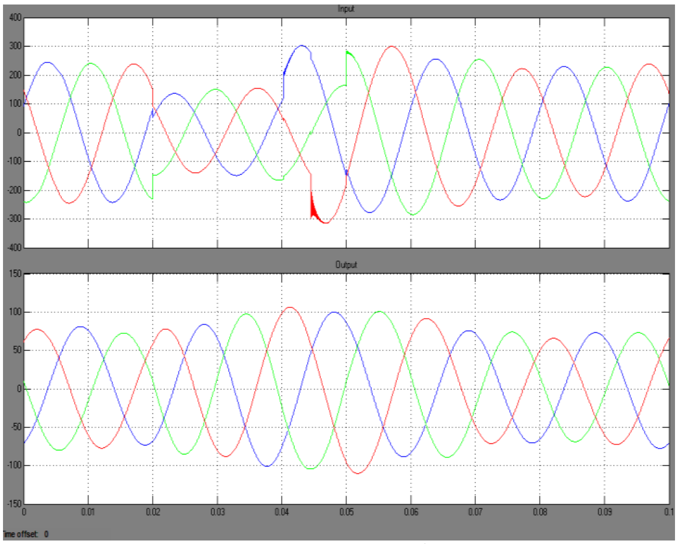

Fig.8. Voltage and Current Control of IPFC 3&1

V. CONCLUSION

The damping performance of the IPFC is evaluated by using the validated IPFC small-signal model. The damping performance is also compared with that of a

UPFC. The following results are obtained: The effect of installing an IPFC or UPFC in constant power control mode for the series branch is similar to that of disconnecting the transmission line that contains the series branch; this resulting change in network structure introduces significant changes in the corresponding mode frequencies as well as mode damping. With proper selection of the location of the series branch, the resulting network can be made to exhibit improved damping behavior.

The improved dynamic performance is essentially caused by a virtual change of the network structure rather than by the tuning of controller parameters as is the case with most traditional approaches such as the PSS, hence, the feedback damping controller design can usually be avoided. It is theoretically possible that poorly damped modes still exist in the changed network; if so; a suitable damping controller can be introduced that modulates the power references of the FACTS device. Since the IPFC has more series branches than the UPFC, it provides more opportunities for network segmentation and, hence, has the potential for greater damping improvement.

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BIOGRAPHY

Dr.Govindaraj Thangavel born in Tiruppur , India , in 1964. He received the B.E. degree from Coimbatore Institute of Technology, M.E. degree from PSG College of Technology and Ph.D. from Jadavpur University, Kolkatta, India in 1987, 1993 and 2010 respectively. His Biography is included in Who's Who in Science and Engineering 2011-2012 (11th Edition). Scientific Award of Excellence 2011 from American Biographical Institute (ABI). Outstanding Scientist of The 21st century by International Biographical centre of Cambridge, England 2011.

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Research,World Academy of Science, Engineering and Technology,Journal of Electrical and Control Engineering（JECE),Applied Computational Electromagnetics Society etc.. He has published 132 research papers in International/National Conferences and Journals. Organized 40 National / International Conferences/Seminars/Workshops. Received Best paper award for ICEESPEEE 09 conference paper. Coordinator for AICTE Sponsored SDP on special Drives,2011.Coordinator for AICTE Sponsored National Seminar on Computational Intelligence Techniques in Green Energy, 2011.Chief Coordinator and Investigator for AICTE sponsored MODROBS - Modernization of Electrical Machines Laboratory. Coordinator for AICTE Sponsored International Seminar on "Power Quality Issues in Renewable Energy Sources and Hybrid Generating System", July 2013.

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