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REVIEW AND OPERATION OF IPFC DEVICE FOR POWER FLOW CONTROL IN POWER SYSTEM

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I. INTRODUCTION

With increasing applications of nonlinear and electronically switched devices in distribution systems and industries, power-quality (PQ) problems, such as harmonics, flicker, and imbalance have become serious concerns. In addition, lightning strikes on transmission lines, switching of capacitor banks, and various network faults can also cause PQ problems, such as transients, voltage sag/swell, and interruption. On the other hand, an increase of sensitive loads involving digital electronics and complex process controllers requires a pure sinusoidal supply voltage for proper load operation.

In order to meet PQ standard limits, it may be necessary to include some sort of compensation. Modern solutions can be found in the form of active rectification or active filtering. A shunt active power filter is suitable for the suppression of negative load influence on the supply network, but

If there are supply voltage imperfections, a series active power filter may be needed to provide full compensation. In recent years, solutions based on flexible ac transmission systems (FACTS) have appeared. The application of FACTS concepts in distribution systems has resulted in a new generation of compensating devices. It consists of combined series and shunt converters for simultaneous compensation of voltage and current imperfections in a supply feeder. Recently, multi converter FACTS devices, such as an interline power-flow controller (IPFC) and the generalized unified power-flow controller (GUPFC) are introduced. The aim of these devices is to control the power flow of multi lines or a sub network rather than control the power flow of a single line by, for instance, a UPFC. When the power flows of two lines starting in one substation need to be controlled, an interline power flow controller (IPFC) can be used.
An IPFC consists of two series VSCs whose dc capacitors are coupled. This allows active power to circulate between the VSCs. With this configuration, two lines can be controlled simultaneously to optimize the network utilization. The GUPFC combines three or more shunt and series converters. It extends the concept of voltage and power-flow control beyond what is achievable with the known two-converter UPFC.

In this paper a power flow management in interline (IPFC), capable of simultaneous compensation for voltage and current in multi-bus/multi-feeder systems is presented. The system is extended by adding a series-VSC in an adjacent feeder. The proposed topology can be used for simultaneous compensation of voltage and current imperfections in both feeders by sharing power compensation capabilities between two adjacent feeders which are not connected. The system is also capable of compensating for interruptions without the need for a battery storage system and consequently without storage capacity limitations.

II.POWER QUALITY & FACTs

The contemporary container crane industry, like many other industry segments, is often enamoured by the bells and whistles, colourful diagnostic displays, high speed performance, and levels of automation that can be achieved. Although these features and their indirectly related computer based enhancements are key issues to an efficient terminal operation, we must not forget the foundation upon which we are building. Power quality is the mortar which bonds the foundation blocks. Power quality also affects terminal operating economics, crane reliability, our environment, and initial investment in power distribution systems to support new crane installations. To quote the utility company newsletter which accompanied the last monthly issue of my home utility billing: ‘Using electricity wisely is a good environmental and business practice which saves you money, reduces emissions from generating plants, and conserves our natural resources.’

POWER QUALITY PROBLEMS

For the purpose of this article, we shall define power quality problems as: ‘Any power problem that results in failure or mis-operation of customer equipment manifests itself as an economic burden to the user, or produces negative impacts on the environment.’
When applied to the container crane industry, the power issues which degrade power quality include:

• Power Factor
• Harmonic Distortion
• Voltage Transients
• Voltage Sags or Dips
• Voltage Swells

The AC and DC variable speed drives utilized on board container cranes are significant contributors to total harmonic current and voltage distortion. Whereas SCR phase control creates the desirable average power factor, DC SCR drives operate at less than this. In addition, line notching occurs when SCR's commutate, creating transient peak recovery voltages that can be 3 to 4 times the nominal line voltage depending upon the system impedance and the size of the drives. The frequency and severity of these power system disturbances varies with the speed of the drive. Harmonic current injection by AC and DC drives will be highest when the drives are operating at slow speeds. Power factor will be lowest when DC drives are operating at slow speeds or during initial acceleration and deceleration periods, increasing to its maximum value when the SCR's are phased on to produce rated or base speed. Above base speed, the power factor essentially remains constant. Unfortunately, container cranes can spend considerable time at low speeds as the operator attempts to spot and land containers. Poor power factor places a greater KVA demand burden on the utility or engine-alternator power source. Low power factor loads can also affect the voltage stability which can ultimately result in detrimental effects on the life of sensitive electronic equipment or even intermittent malfunction. Voltage transients created by DC drive SCR line notching, AC drive voltage chopping, and high frequency harmonic voltages and currents are all significant sources of noise and disturbance to sensitive electronic equipment

III. POWER QUALITY ISSUES AND ITS CONSEQUENCES

Power quality problem is any power problem manifested in voltage, current, or frequency deviation that results in failure or malfunctioning of customer equipment. Power quality is a two-pronged issue, with electronic equipment playing both villain and victim. Most new electronic equipment, while more efficient than its mechanical predecessors, consumes electricity differently than traditional mechanical appliances. Power supply quality issues and resulting problems are consequences of the increasing use of solid state switching devices, nonlinear and power electronically switched loads, electronic type loads .the advent and wide spread of high power semiconductor switches at utilization, distribution and transmission leaves have non sinusoidal currents.

Cost of poor power quality:-

Poor Power Quality can be described as any event related to the electrical network that ultimately results in a financial loss. Possible consequences of poor Power Quality includes as follows:-
Unexpected power supply failures (breakers tripping, fuses blowing).

1. Equipment failure or malfunctioning.
2. Equipment overheating (transformers, motors) leading to their lifetime reduction.
3. Damage to sensitive equipment (PC's, production line control systems).
4. Electronic communication interferences.
5. Increase of system losses.
6. Need to oversize installations to cope with additional electrical stress with consequential increase of installation and running costs and associated higher carbon footprint.
7. Penalties imposed by utilities because the site pollutes the supply network too much.

The following are the main contributors to Low Voltage poor Power Quality can be defined:-
1. Reactive power, as it loads up the supply system unnecessary, Harmonic pollution, as it causes extra stress on the networks and makes installations run less efficiently,
2. Load imbalance, especially in office building applications, as the unbalanced loads may result in excessive voltage imbalance causing stress on other loads connected to the same network, and leading to an increase of neutral current and neutral to earth voltage build-up,
3. Fast voltage variations leading to flicker.

Compensation in power system:-
Except in a very few special situations, electrical energy is generated, transmitted, distributed, and utilized as alternating current (A.C.). However, alternating current has several distinct disadvantages. One of these is the necessity of reactive power that needs to be supplied along with active power. Reactive Power can be leading or lagging. While it is the active power that contributes to the energy consumed, or transmitted, reactive power does not contribute to the energy. Reactive power is an inherent part of the total power.

IV. ROLE OF IPFC IN FACTS

Basic principle of IPFC:-

The involvement of a new family of FACTS devices which is based on Voltage Source Converters (VSC) added the features like flexible power flow control, transient stability and power system oscillation damping enhancement. The UPFC provide independent control both for the real and reactive power flow of individual transmission lines thereby providing the cost effective utilization. While the Interline Power Flow Controller (IPFC) concept provides compensation in a number of transmission lines.

The interline power flow controller (IPFC) is one of the latest FACTS controller used to control power flows of multiple transmission lines. Interline Power Flow Controller (IPFC) is an extension of static synchronous series compensator (SSSC). Any converters within the
IPFC can transfer real power to any other and hence real power transfer among the lines may be carried out, together with independently controllable reactive series compensation of each individual line. IPFC employs a number of VSCs linked at the same DC terminal, each of which can provide series compensation for its own line. In this way, the power optimization of the overall system can be realized in the form of appropriate power transfer through the common DC link from overloaded lines to under-loaded lines. The power flow control design for IPFC is proposed and transfer functions are analyzed in this thesis. In its general form the interline power flow controller employs number of DC to AC inverters each providing series compensation for a different line as shown in Fig.4.1. IPFC is designed as a power flow controller with two or more independently controllable static synchronous series compensators (SSSC) who are solid state voltage source converters injecting an almost sinusoidal voltage at variable magnitude and are linked via a common DC capacitor. SSSC is employed to increase the transferable active power on a given line and to balance the loading of a transmission network.

In addition, active power can be exchanged through these series converters via the common DC link in IPFC. It is noted that the sum of the active powers outputted from VSCs to transmission lines should be zero when the losses of the converter circuits can be ignored. A combination of the series connected VSC can inject a voltage with controllable magnitude and phase angle at the fundamental frequency while DC link voltage can be maintained at a desired level. The common DC link is represented by a bidirectional link for active power exchange between voltage sources.

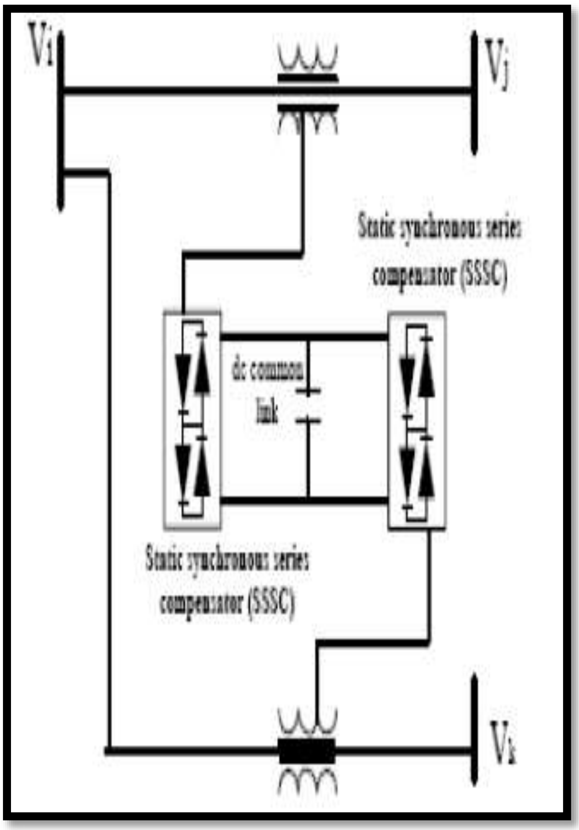

Fig 4.1-Schematic representation of IPFC

Generalized Interline Power Flow Controller:-

There can be compensation requirements for particular multi-line transmission systems which would not be compatible with the basic constraint of the IPFC, stipulating that the sum of real power exchanged with all the lines must be zero. This constraint can be circumvented by a generalized IPFC arrangement, in which a shunt connected inverter, is added to the number of inverters providing series compensation as illustrated in fig 4.2.

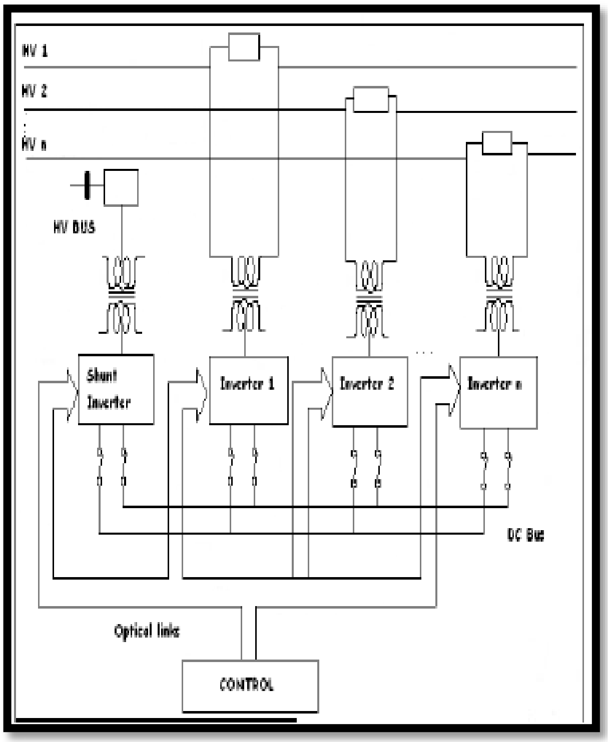

Fig 4.2: A Generalized Interline Power Flow Controller for Power Transmission Management

With this scheme the net power difference at the ac terminal is supplied or absorbed by the shunt inverter, and ultimately exchanged with the ac system at the shunt bus. This arrangement can be economically attractive, because the shunt inverter has to be rated only for the maximum real power difference anticipated for the whole system. It can also facilitate relatively inexpensive shunt reactive compensation, if this is needed at the particular substation bus.

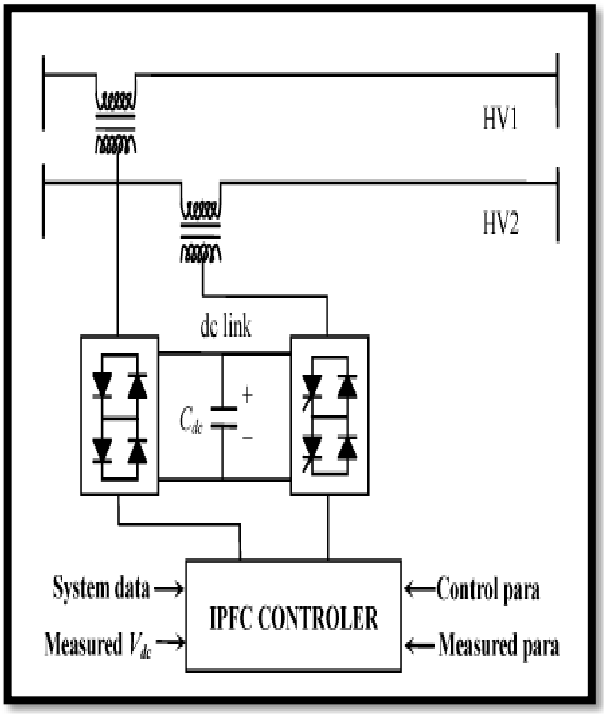

Fig-4.3. Schematic diagram of two-converter IPFC

V. MODELLING AND SIMULATION

IPFC MODELLING

The IPFC is the most versatile and effective device. The IPFC consists of voltage source converters; connected one in series and the other in shunt and both are connected back to back through a D.C capacitor. The injection model of IPFC device is explained above. The fig-5.1 shows the injection model of IPFC located between buses i and j and its phasor diagram are shown in fig-5.2.

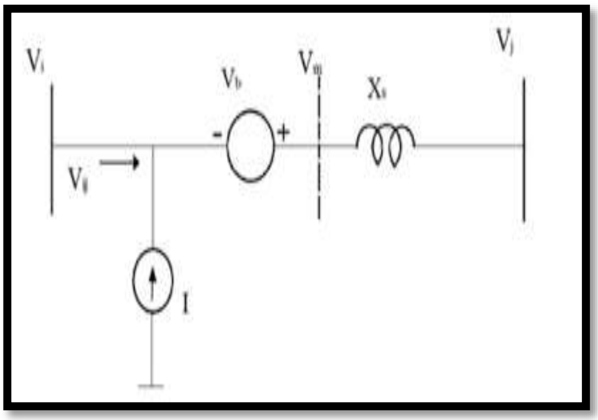

Fig-5.1-Injection model of IPFC

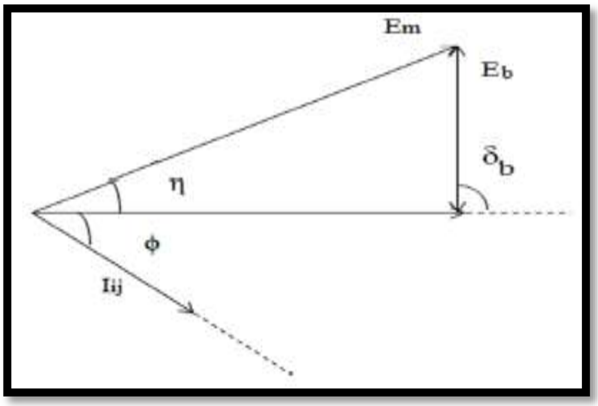

Fig 5.2-Phasor diagram

Three Phase system without IPFC

The simulation model of series compensated transmission system is shown in fig below. The simulation results also shown in fig below:-

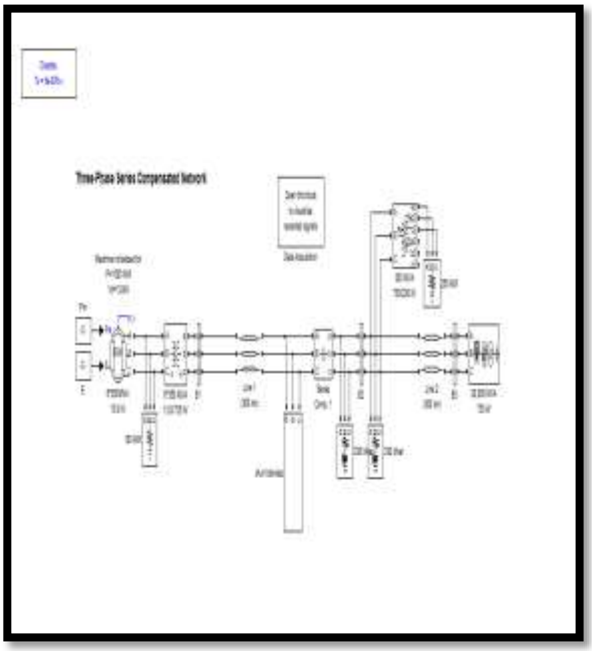

Fig 5.1- Three phase series compensated network without IPFC device

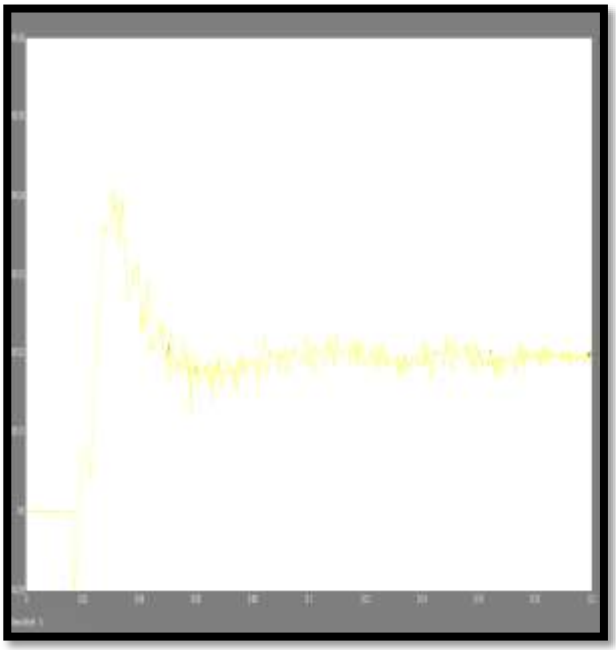

Fig 5.2- Simulation Results of 3-phase voltage Vabc

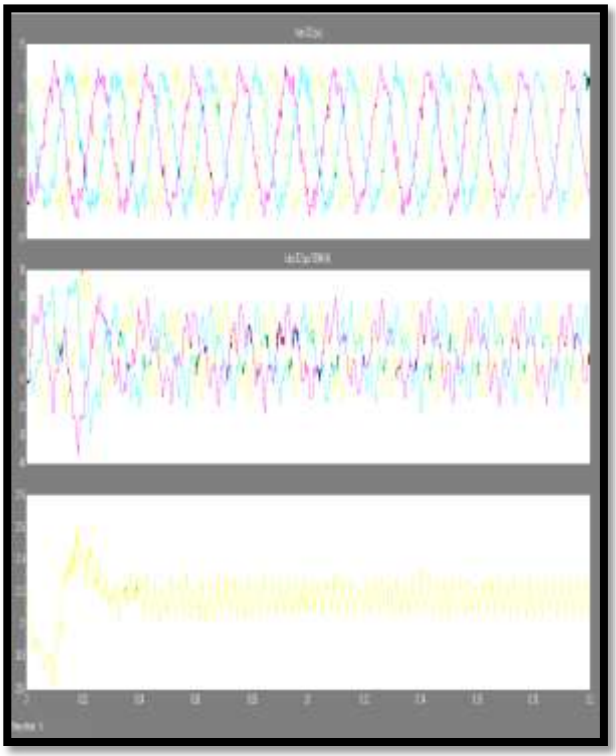

Fig 5.3-Vabc, Iabc, Real and Reactive power (Case-I)

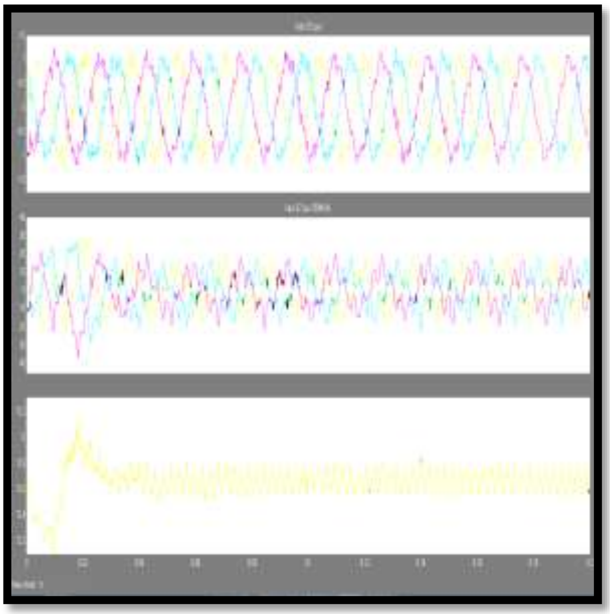

Fig 5.4-Vabc, Iabc, Real and Reactive power (Case-II)

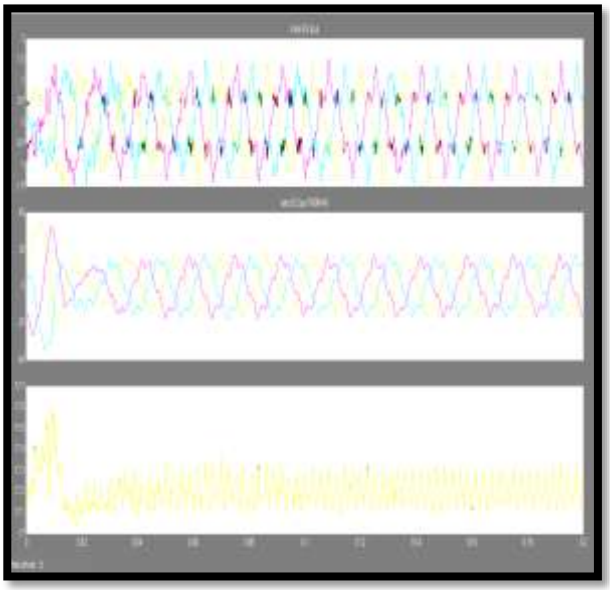

Fig 5.5-Vabc, Iabc, Real and Reactive power (Case-III)

Three Phase System with IPFC Device

The voltage source converter topology is provided for power flow management in IPFC. There is two voltage source converter provided at input side of IPFC and one VSC is provided at output side.

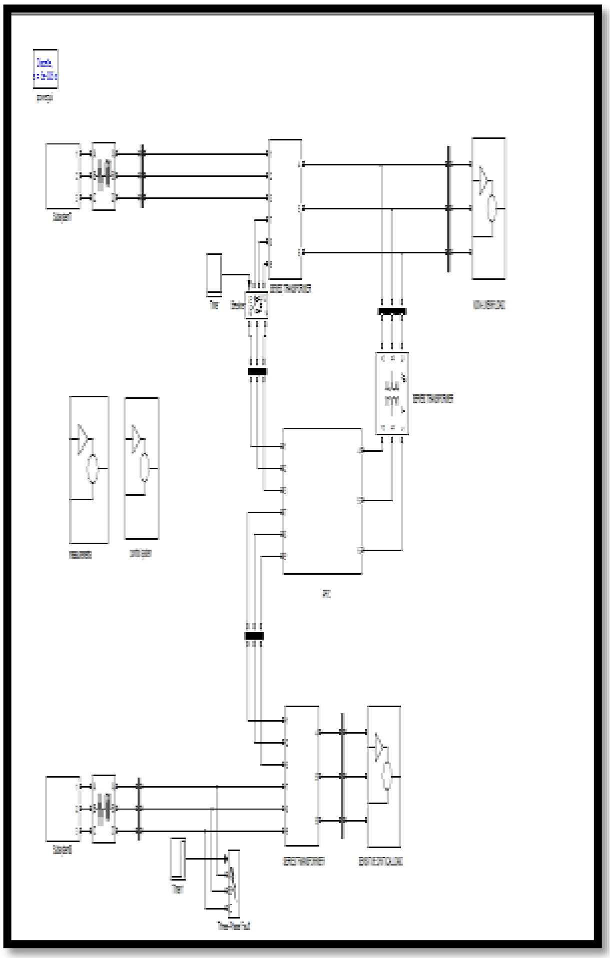

Fig 5.6-Three phase system connected with IPFC device

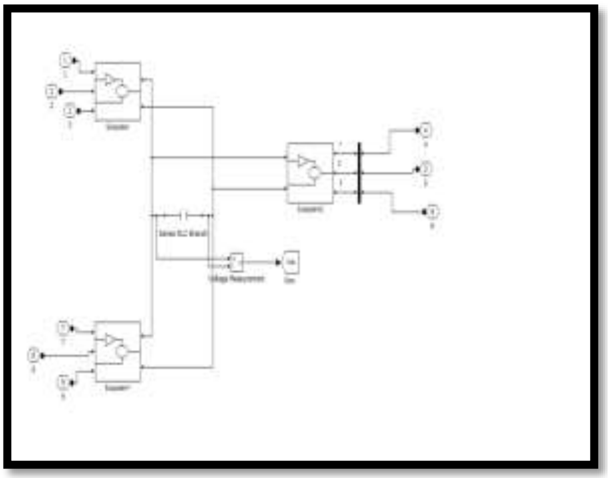

Fig 5.7-IPFC device subsystem

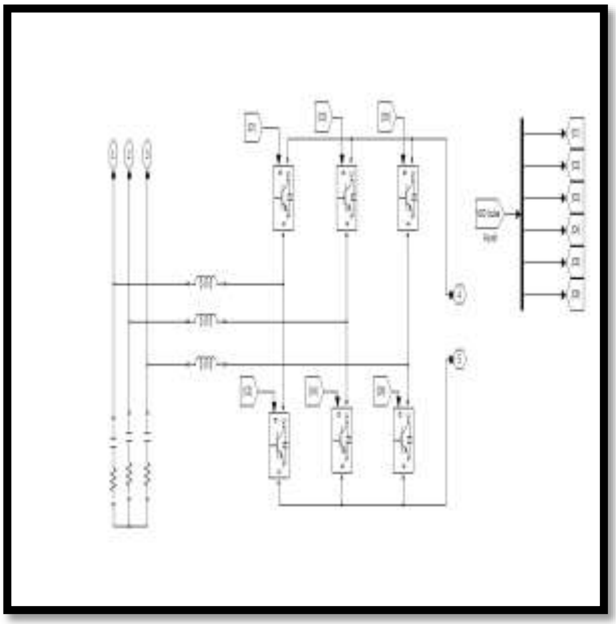

Fig 5.8-VSC configuration in IPFC

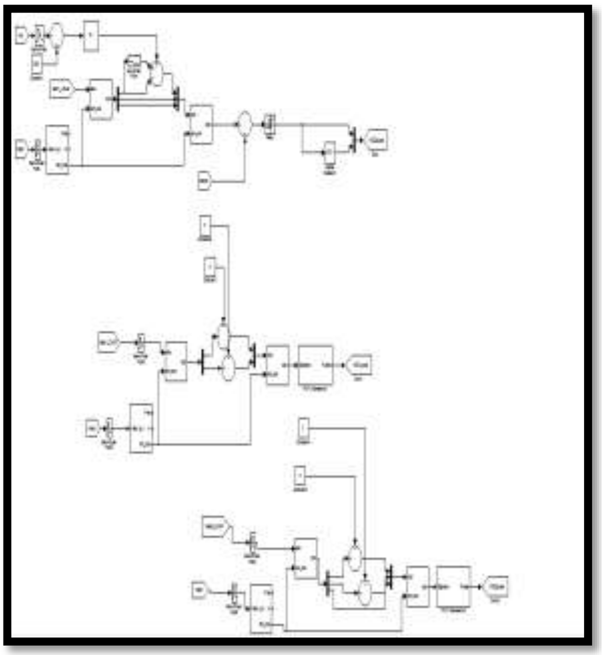

Fig 5.9-control circuit for IPFC device

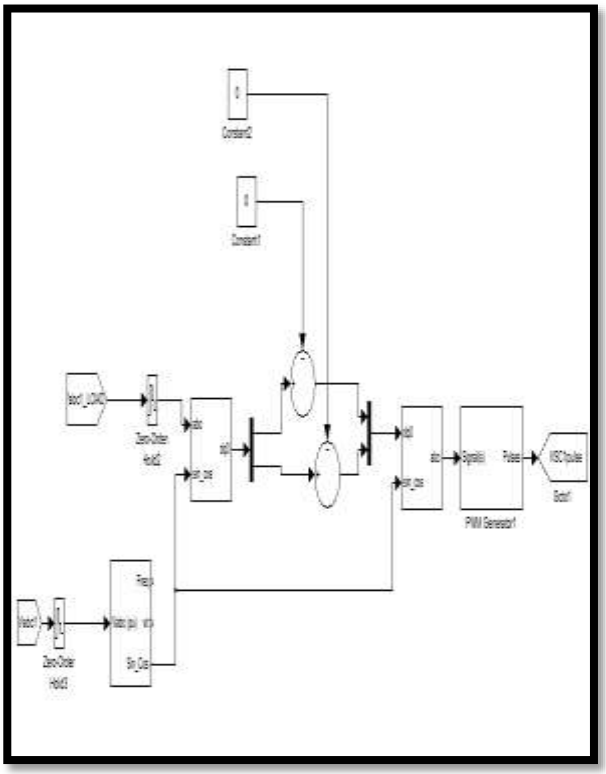

Fig 5.10-Input side VSC control circuit

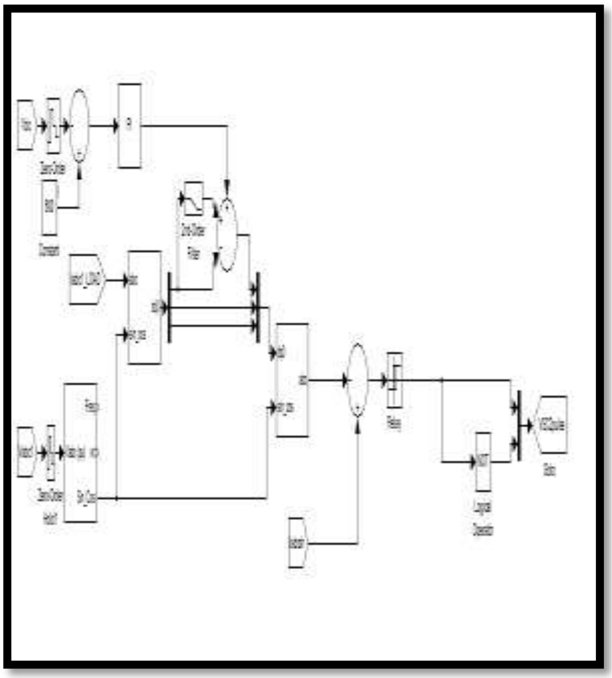

Fig 5.11-Load side VSC control Circuit in IPFC

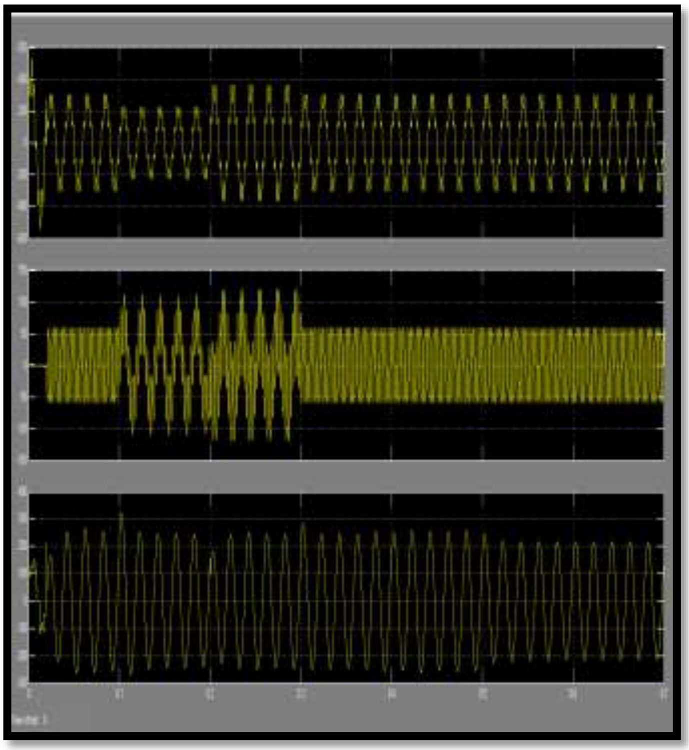

Fig 5.12-(a) Vabc at input side (b) Vabc between series transformer and IPFC (c) Vabc at load side for bus-1

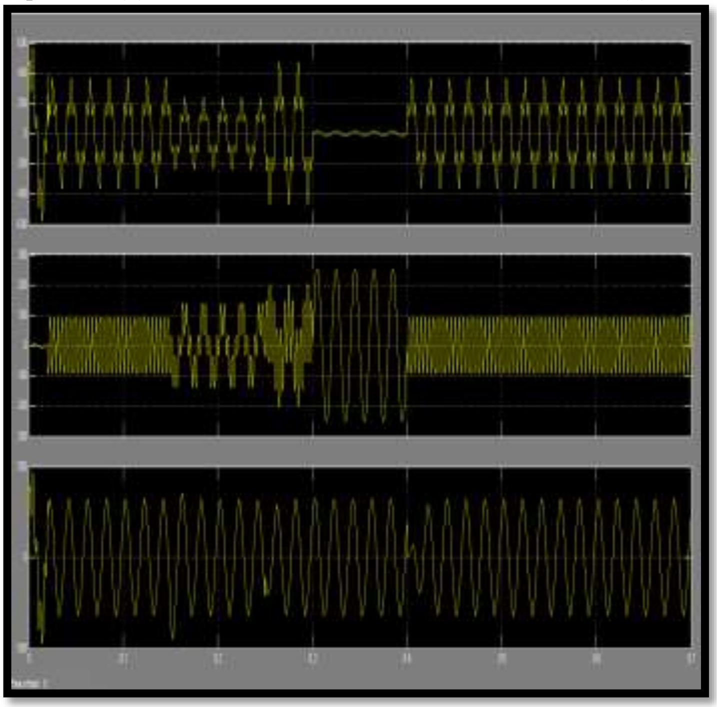

Fig 5.13-(a) Vabc at input side (b) Vabc between series transformer and IPFC (c) Vabc at load side for bus-2

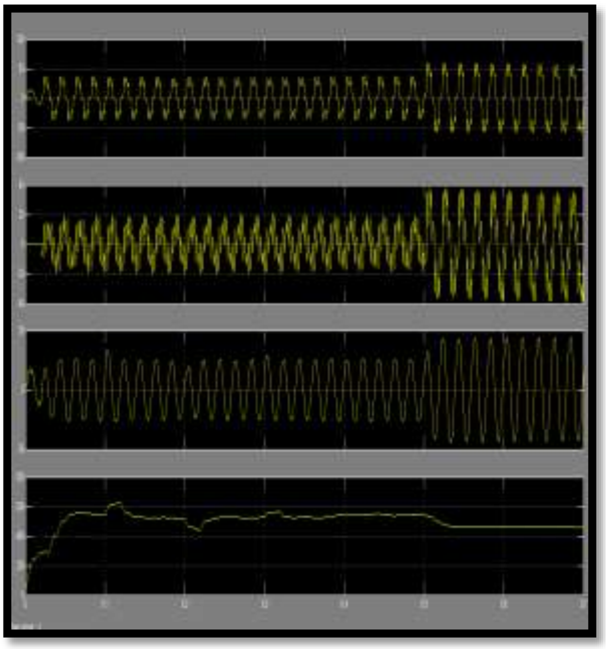

Fig 5.14-(a) Iabc at input side (b) Iabc between series transformer and IPFC (c) Iabc at load side for bus-1 (d) D.C voltage at Common link D.C Capacitor

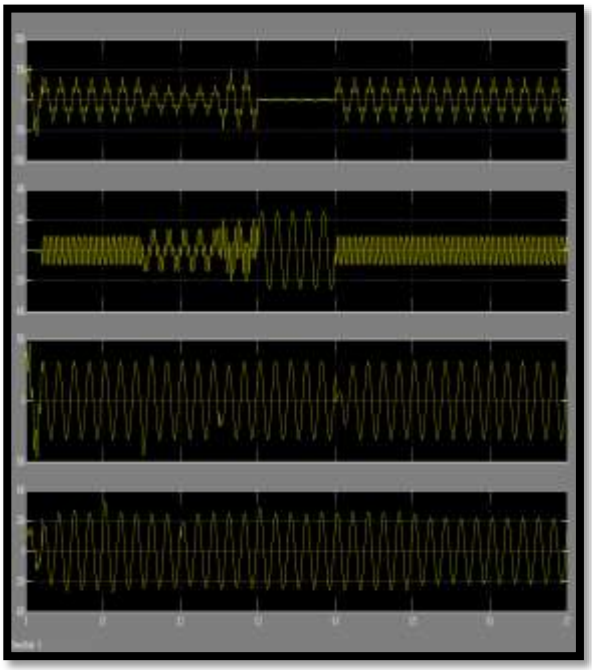

Fig 5.15-(a) Vabc at input side (b) Vabc between series transformer and IPFC (c) Vabc at load side for bus-2 (d) Vabc at load side for bus-1

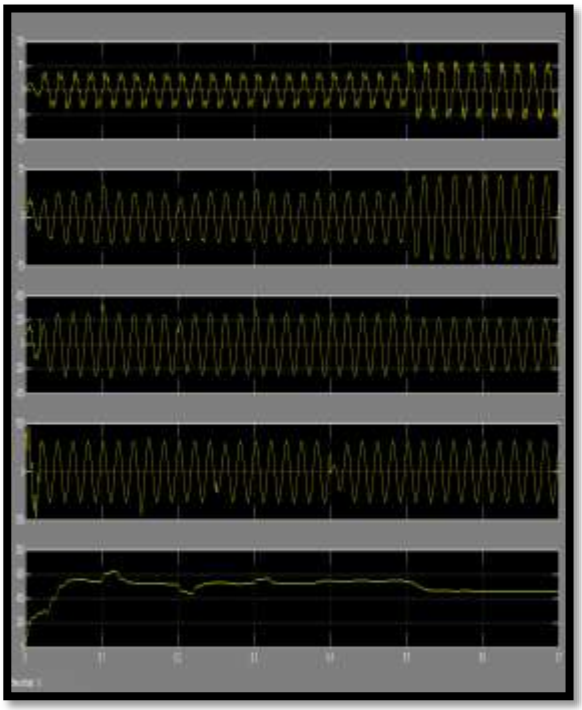

Fig 5.16- load current values for bus-1 and bus-2 and D.C voltage at Common link D.C Capacitor

CONCLUSION

In this paper voltage and power profile has been improved through implementation of IPFC. IPFC is capable of balancing the power through the multiple transmission lines. The power quality is improved since IPFC permits additional power in the system. The circuit models for IPFC system are developed using Matlab- Simulink software. With these simulation results it can be inferred that with the implementation of IPFC, voltage profile, real power flow and reactive power flow can be controlled. The IPFC modelling has been with PI controller for power quality enhancement and power flow control of the given system.

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