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Pid Controller Based Power Quality Improvement Using Statcom

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Abstract-

At present, electrical network stability is of the utmost importance because of the increase in electric demand and the integration of distributed generation deriving from renewable energy. In this paper, we proposed a static reactive power compensator model with common direct current voltage sources. Converter parameters were calculated and designed to fulfill specifications. In order to ascertain the device response for different operating modes as reactive power consumer and generator, we developed the model's power and control circuits in Matlab Simulink.

Key Words: MATLAB/SIMULINK, STATCOM, Inverter, Reactive Power, PWM, PCC.

I. INTRODUCTION

Modern power system is a huge complex network comprising of number of generators, transmission lines, different types of loads and transformers. Because of the increasing power demand, nowadays transmission lines are more loaded than was planned when they were built. As the load on the transmission lines is increasing day by day the problem of transient stability after a serious fault can become a transmission limiting factor. Power engineers are much more concerned about transient stability problem because of the blackout in northeast United States, Scandinavia, England and Italy. The ability of a system to maintain synchronous operation in the event of large disturbances such as switching of lines or multiphase short circuit faults is called as Transient stability. The response of the output resulting system consists of the huge interruption of generator rotor angles and is affected by the non-linearity in the power angle relationship. The initial operating conditions of the system as well as the severity of the disturbance are important because stability is dependent on them [1]. Power electronics has introduced recently the use of flexible ac transmission system (FACTS) controllers in electrical power systems. The FACTS controllers operates in a very fast manner which is a very important and necessary feature can be utilized to improve the voltage stability, and steady state and transient stability of the complex electrical power system. Therefore FACTS devices are utilized in the electrical power system which reduces the need of constructing new transmission lines which increases the efficiency of the electrical power system. The voltage control at the required bus can be done by the first generation FACTS device Static VAR Compensator (SVC) which results in the improvement of the voltage profile of power system. The main function of SVC is used to maintain the voltage at a particular bus with the help of reactive power compensation (acquired by changing the firing angle of the thyristors) [2- 4]. Compared with classical shunt compensation, SVCs have been used for voltage control of high performance steady state and transient condition. By optimized reactive power control SVCs are also applied for damping power swings, improve transient stability and reduce system losses [1]. The next generation of flexible ac transmission system (FACTS) devices is Static Synchronous Compensator (STATCOM). The STATCOM is used in the electrical power system for different purposes such as line loss minimization, reactive power compensation, power oscillation damping etc. The Static Synchronous Compensator is a combination of voltage source converter in parallel with the capacitor which acts as a DC energy source link tied to the transmission line. Almost sinusoidal current of variable magnitude at the point of connection is injected by the STATCOM.

The compensator has two effects which appeared immediately. The first one is it alters no load supply point voltage and second is it modifies sensitivity of supply point voltage to load reactive power. There are two types of compensators, active and passive compensators. Normally the passive compensators include the devices which are permanently connected for step less variation of reactive power. Generally shunt devices are included in active compensators. These compensators maintain constant voltage at the bus terminals to which they are connected. The FACTS devices in the second generation are static compensators which consist of half controlled devices i.e. of thyristor based and fully controlled devices such as STATCOM, SVC, SSSC, etc. [1] Basically there are four types of FACTS controllers: A] Shunt Controller B] Series Controller C] Shunt-Series Controller D] Series-Series Controller The series controller injects the voltage in series with the transmission line with any phase angle according to driving voltage to control the line current. The shunt controller draws or injects the current into the power system. The combination of shunt and series controller could inject the current via shunt controller of the system and injects the voltage via series controller of the system. These are coordinately control. The combined Series-Series controller provides independent reactive power compensation with the transmission of real power via DC link. In multiline transmission system these types of controller are used which controlled coordinately. The list of all controllers is given in Table I. The STATCOM is shunt connected device which is used for compensation, either by injecting or absorbing reactive power. Many researchers contributed their research on reactive power compensation. In this paper the STATCOM is controlled by vector control method. The vector control strategy is mainly used for controlling three phase induction motor. The fast response is achieved by controlling flux and torque producing components.

II. RESEARCH GAP

In 1991, a ±80 MVar STATCOM developed by KEPCO and Mitsubishi Motors was installed at Inuyama Switching Station to improve stability of a 154 kV system [4]. Tennessee valley authority (TVA), together with EPRI and Westinghouse, installed a ±100 MVar STATCOM [5, 6] Sullivan 500 kV Transformer Substation in October 1996 and it kept in good operation since then. In 1997, Siemens installed an 8 MVA

STATCOM at RejsbyHede wind farm to provide dynamic control of wind generators [7]. In July 1997, American Electric Power (AEP), cooperating with Westinghouse Electric Company, developed a ±160 MVA STATCOM and EPRI, as the parallel part of first Unified Power Flow Controller (UPFC) installed at Inez Station in eastern Kentucky [8]. EPRI and Siemens also developed a ±200 MVar STATCOM, which was installed at Marcy 345 kV substation in February 2001 [9]. In early 2001, a 175 MVar STATCOM developed by ALSTOM, the first cascade multilevel-inverter-based STATCOM in the world, entered commercial service at NGC (National Grid Company) East Claydon, England [10]. A + 133/-41 MVar STATCOM system has been installed at the Vermont Electric Power Company's Essex 115 kV substation since May 2001, to compensate for heavy increases in summertime electric usage [11]. A three-level ±100 MVar STATCOM is installed by San Diego Gas & Electric (SDG&E) at Talega substation, California in October 2002, and is to be extended to a Back-To-Back system [12]. An 80 MVar UPFC developed by Korea Electric Power Corporation is under installation and ready for commercial operation from year 2003 [13].

III. BASIC OF STATCOM

Depending on their connection method to the network, they can be split into series and parallel networks. Among parallel-connected devices, the static synchronous compensator (STATCOM) stands out, whose first prototype was developed in Japan in 1980 [4]. It emerged as a solution to the limitations that the Static Var Compensator (SVC) shows, as the proposed device suppresses SVC's huge capacitors and reactors. In [7], a 20MVA prototype is presented, with an output VAR loss of around 3%, and for this reason, its commercial development is suggested in the future. Due to the shortage of power switching elements, interest in researching this device was reduced. Nevertheless, with the breakthrough of self-switching devices, postponed research works were resumed in Asia, America, and Europe; and, in this way, in recent years the real potential of these devices has been taken advantage of. A Static Synchronous Compensator (STATCOM) has the capability of supplying or absorbing reactive energy in order to offset deficiencies in electrical quality at the load connection point to the electrical network. Its technology stems from the Voltage Source Converter (VSC) implemented from converters with IGBTs, which allow a highpower compensation, with scarce harmonic injection [5]. Because of their design, the STATCOM's have the ability to provide a quick reply by injecting current to keep a stable system voltage during network failures, thus improving short-term voltage stability [6,7]. Additionally, STATCOM allows power factor correcting, reactive power controlling, damping of low-frequency power swings by reactive power modulation, harmonic filtering, flicker mitigation, and power quality improving [8–10]. The STATCOM operation is akin to a synchronous compensator. Whether the Converter-generated voltage is less than the transmission system voltage, it acts as an inductive load, absorbing reactive power from the network. In contrast, when the Converter output voltage is higher than the network voltage, STATCOM acts as a capacitor, providing reactive power to the system. These devices operate effectively when non-linear and/or unbalanced loads are connected [2]. Nowadays, these devices have been successfully employed in power grid substations, since they have faster response times, compact structures, wider compensation ranges, and do not require wide surfaces to be placed in. Therefore, the Static Synchronous Compensators are widely suitable for load compensation in modern three-phase power distribution systems that integrate renewable energy sources [3].

One of the many devices under the FACTS family, a STATCOM is a regulating device which can be used to regulate the flow of reactive power in the system independent of other system parameters. STATCOM has no long term energy support on the dc side and it cannot exchange real power with the ac system. In the transmission systems, STATCOMs primarily handle only fundamental reactive power exchange and provide voltage support to buses by modulating bus voltages during dynamic disturbances in order to provide better transient characteristics, improve the transient stability margins and to damp out the system oscillations due to these disturbances. A STATCOM consists of a three phase inverter (generally a PWM inverter) using SCRs, MOSFETs or IGBTs, a D.C capacitor which provides the D.C voltage for the inverter, a link reactor which links the inverter output to the a.c supply side, filter components to filter out the high frequency components due to the PWM inverter. From the d.c. side capacitor, a three phase voltage is generated by the inverter. This is synchronized with the a.c supply. The link inductor links this voltage to the a.c supply side. This is the basic principle of operation of STATCOM

IV. PROBLEM FORMULATION

The main purpose of power system is to generate & transmit power via transmission line to various consumers efficiently. It is a complex process. There are many components takes place in power system, one of the main components to form a major part is the reactive power in the system. Various loads like motor loads and other loads require reactive power for their operation. The majority of power consumption has been drawn in inductive loads. These loads are operated as lagging power factor. The feeder power losses are increased due to reactive power and also the flow of active power is disturbed in distribution system.

V. REACTIVE POWER

Reactive power is the power that supplies the stored energy in reactive elements. Power, as we know, consists of two components, active and reactive power. The total sum of active and reactive power is called as apparent power. In AC circuits, energy is stored temporarily in inductive and capacitive elements, which results in the periodic reversal of the direction of flow of energy between the source and the load. The average power after the completion of one whole cycle of the AC waveform is the real power, and this is the usable energy of the system and is used to do work, whereas the portion of power flow which is temporarily stored in the form of magnetic or electric fields and flows back and forth in the transmission line due to inductive and capacitive network elements is known as reactive power. This is the unused power which the system has to incur in order to transmit power. Inductors (reactors) are said to store or absorb reactive power, because they store energy in the form of a magnetic field. Therefore, when a voltage is initially applied across a coil, a magnetic field builds up, and the current reaches the full value after a certain period of time. This in turn causes the current to lag the voltage in phase.

Need for Reactive power compensation. The main reason for reactive power compensation in a system is:

1) The voltage regulation;

2) Increased system stability;

3) Better utilization of machines connected to the system;

4) Reducing losses associated with the system; and

5) To prevent voltage collapse as well as voltage sag.

The impedance of transmission lines and the need for lagging VAR by most machines in a generating system results in the consumption of reactive power, thus affecting the stability limits of the system as well as transmission lines. Unnecessary voltage drops lead to increased losses which needs to be supplied by the source and in turn leading to outages in the line due to increased stress on the system to carry this imaginary power. Thus we can infer that the compensation of reactive power not only mitigates all these effects but also helps in better transient response to faults and disturbances. In recent times there has been an increased focus on the techniques used for the compensation and with better devices included in the technology, the compensation is made more effective. It is very much required that the lines be relieved of the obligation to carry the reactive power, which is better provided near the generators or the loads. Shunt compensation can be installed near the load, in a distribution substation or transmission substation.

A proportional–integral–derivative controller (PID controller or three-term controller) is a control loop mechanism employing feedback that is widely used in industrial control systems and a variety of other applications requiring continuously modulated control. A PID controller continuously calculates an error value as the difference between a desired setpoint (SP) and a measured process variable (PV) and applies a correction based on proportional, integral, and derivative terms (denoted P, I, and D respectively), hence the name.

In practical terms, PID automatically applies an accurate and responsive correction to a control function. An everyday example is the cruise control on a car, where ascending a hill would lower speed if constant engine power were applied. The controller's PID algorithm restores the measured speed to the desired speed with minimal delay and overshoot by increasing the power output of the engine in a controlled manner.

The first theoretical analysis and practical application of PID was in the field of automatic steering systems for ships, developed from the early 1920s onwards. It was then used for automatic process control in the manufacturing industry, where it was widely implemented in at first pneumatic and then electronic controllers. Today the PID concept is used universally in applications requiring accurate and optimized automatic control.

VI. RESULT AND ANALYSIS

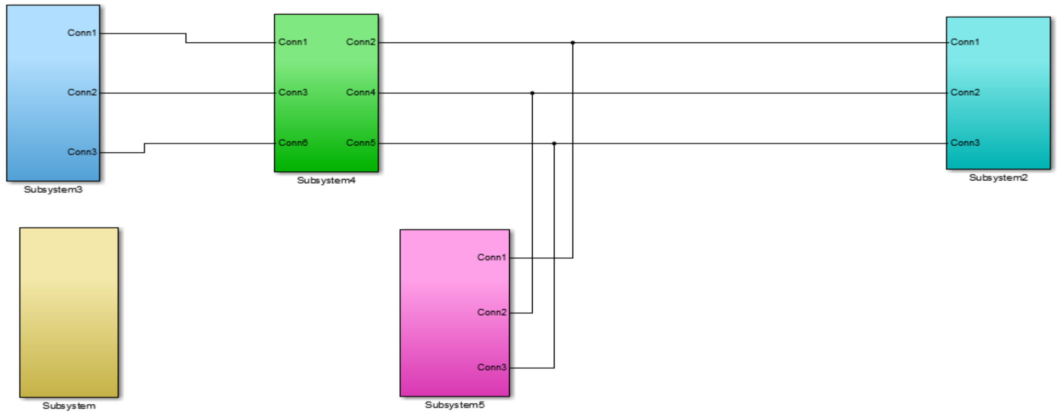

Fig 1.Simulation Model of STATCOM

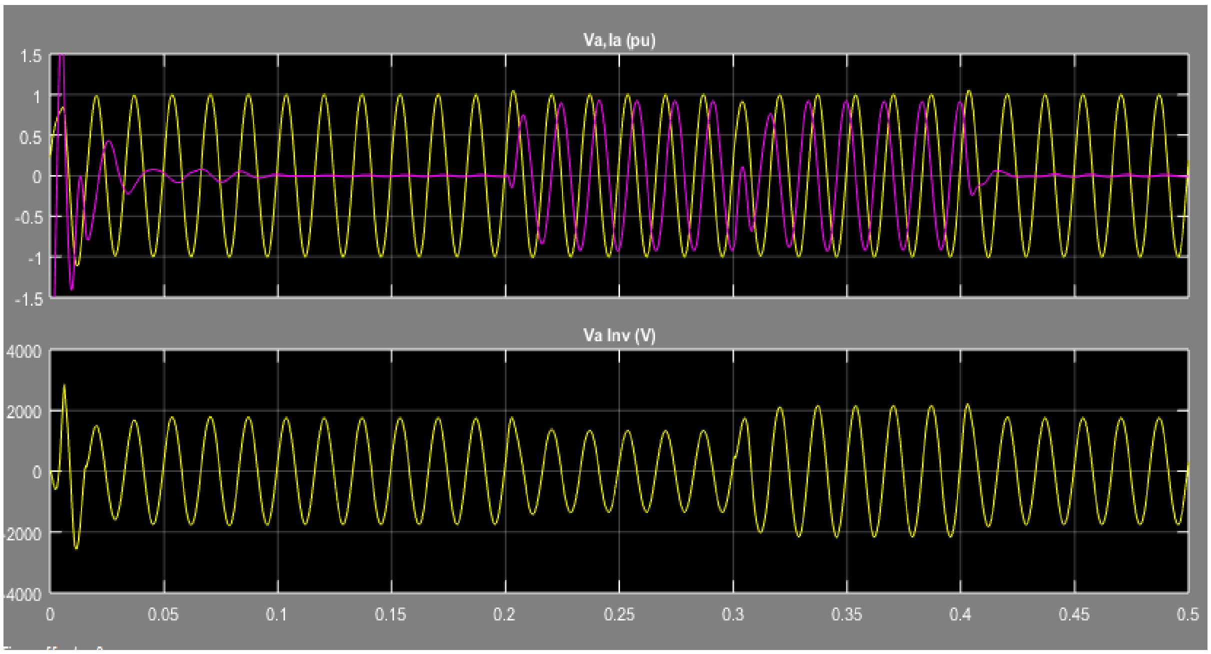

Fig 2. Voltage and Voltage (pu) Index.

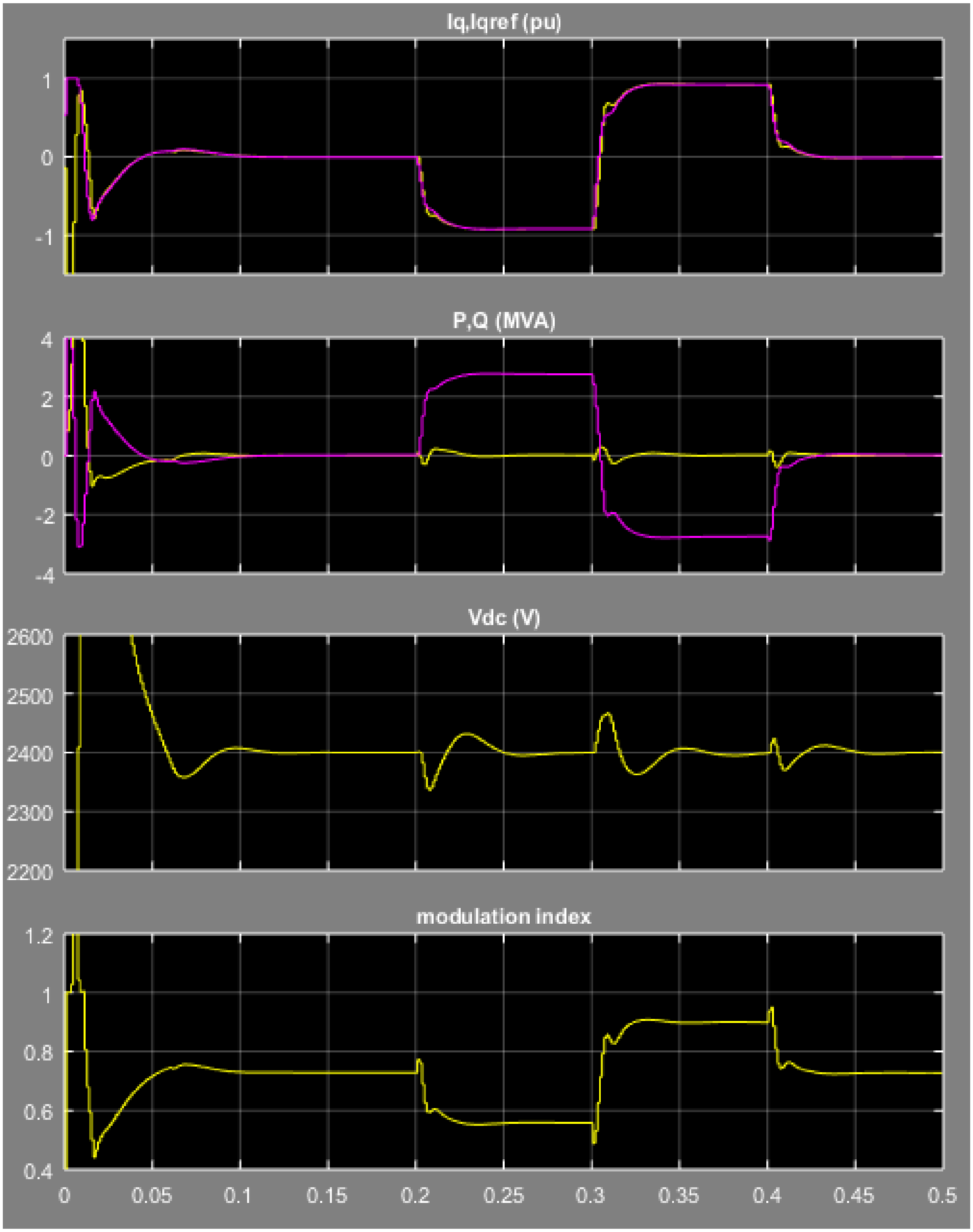

Fig 3. Reference voltage (pu) power, Voltage DC and Modulation Index.

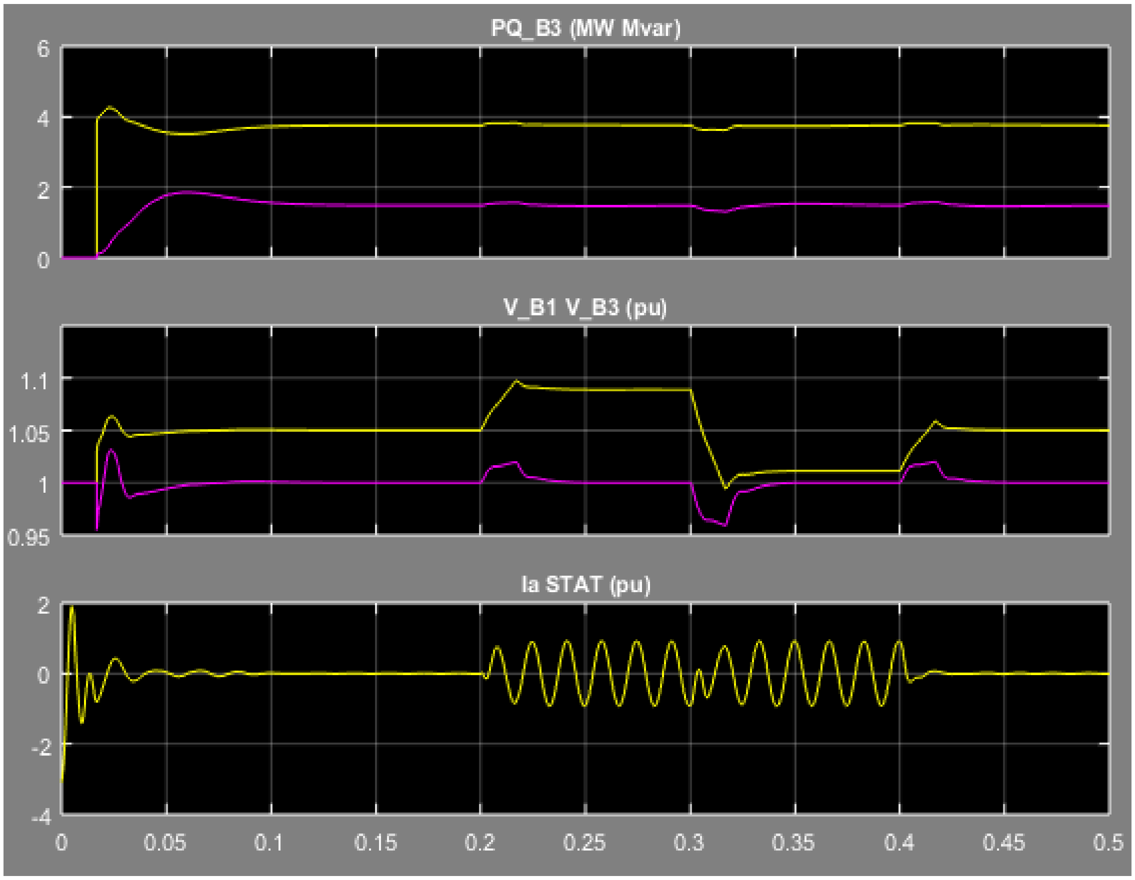

Fig 4. Power, Voltage across BUS and current (pu).

VII. CONCLUSION

The study of the basic principles of the STATCOM is carried out as well as the basics of reactive power compensation using a STATCOM. A power flow model of the STATCOM is attempted and it is seen that the modified load flow equations help the system in better performance. The bus system shows improved plots and the thus we can conclude that the addition of a STATCOM controls the output of a bus in a robust manner.

From the above waveforms, the voltage profile of transmission system is improved after connecting the STATCOM. And we also derived different waveforms for different percentage of reactive power compensated by STATCOM. Therefore, we conclude that, by connecting STATCOM the overall voltage disturbances are reduced and power factor of the system is also improved and overall response of the STATCOM is more efficient than other devices.

The STATCOM is used to improve the power factor of the system. The developed vector control strategy gives better results and fast response for power factor improvement. This simulation is done for fixed DC bus voltage and variable modulation index one can make for variable DC bus voltage and fixed modulation index depending on the application.

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