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A Simulation Model for Reactive Power Compensation

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Abstract: In the modern power system the reactive power compensation is one of the main issues, thus we need to work on the efficient methods by which Var compensation can be done easily and we can optimize the modern power system. Var control technique can provides appropriate placement of compensation devices by which a desirable voltage profile can be achieved and at the same time minimizing the power losses in the system. In this paper the hybrid systems is used for dual compensation of reactive power and DC magnetic bias in distribution systems, and it results in desired real power in the system.
Key Words: Reactive Power, IGBT, FACTS devices

I. INTRODUCTION

Voltage control in an electrical power system is important for proper operation for electrical power equipment to prevent damage such as overheating of generators and motors, to reduce transmission losses and to maintain the ability of the system to withstand and prevent voltage collapse. In general terms, decreasing reactive power causing voltage to fall while increasing it causing voltage to rise. A voltage collapse occurs when the system try to serve much more load than the voltage can support. When reactive power supply lower voltage, as voltage drops current must increase to maintain power supplied, causing system to consume more reactive power and the voltage drops further . If the current increases too much, transmission lines go off line, overloading other lines and potentially causing cascading failures. If the voltage drops too low, some generators will disconnect automatically to protect themselves. Voltage collapse occurs when an increase in load or less generation or transmission facilities causes dropping voltage, which causes a further reduction in reactive power from capacitor and line charging, and still there further voltage reductions. If voltage reduction continues, these will cause additional elements to trip, leading further reduction in voltage and loss of the load. The result in these entire progressive and uncontrollable declines in voltage is that the system unable to provide the reactive power required supplying the reactive power demands.[1]. Reactive power compensation is a very important issue in the operation of electric distribution systems. The load requires reactive power for magnetizing purposes. Reactive power required by the load depending on the nature of the load, which is mainly decided by the magnetic circuit configuration. Reactive power requirement change continuously with the load and voltage level. Voltage control in a distribution system mainly related to the control of var. Reactive power control in addition to control of reactive power in the distribution system may have such advantages as reduction of real power losses and improvement of power factor in the system [2]. Reactive power compensation (Var) and voltage control in power systems can be easily achieved by connecting reactive power compensation devices such as shunt capacitors, series capacitors, static Var compensators, tap changing transformers, and automatic voltage regulators and even now with the new FACTS tools like STATCOMS, UPFC and other FACTS devices. Reactive power supply and voltage control can be provided by transmission facilities, and generation facilities. In competitive electricity markets, Independent System Operators (ISOs) operate the grid, but do not own transmission facilities and generation. Therefore, reactive power must be procured. The cost of installing transmission facilities is normally recovered as part of the cost of basic transmission services. The reactive supply and voltage control from generation facilities is one of the Ancillary Services provided by generators, as identified in Order 888 issued in April 1996. Reactive power support voltages, which must be controlled for reliable power system operation. Insufficient reactive power has been related to several major blackouts worldwide, including August 2003 blackout in the United States and Canada [3]

II. REACTIVE POWER CONTROL IN DISTRIBUTION SYSTEMS

One of the most fundamental and important problems in electric distribution systems is reactive power/voltage control. High voltage difference between voltage in different buses in distribution system is the sole indicator of reactive power imbalance in the system. The main problem is that the voltage drop occurs when reactive power flows through the inductive reactance of power lines and when the system is constrained to supply the normal requirements of reactive power. Voltage problem is compounded when reactive

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power demand increases and is shipped over the already heavily loaded lines.

Reactive power control has been looked at as an important issue in distribution systems for many reasons [4].First, the need for most efficient operation of power systems has increased with the price of fuel. For a given distribution of power, the losses in the system can be reduced by minimizing the flow of reactive power. Second, the extension of the power network specially in the distribution level, has been curtailed in general by high interest rates, and in particular cases by right-of-way. In many cases power transmitted through older networks has been increased, requiring the application of reactive power control measures to restore stability margins. Third, voltage is considered as one of the most important parameters of the quality of power supply. Its deviation from the normal value may be harmful and expensive. Reactive power control is an essential tool in maintaining the quality of supply. An extensive amount of research has appeared dealing with reactive power control in power systems. In general, most of this research falls within the following subgroups of the Var/voltage control problems. The reactive power planning and operation is an optimization problem of nonlinear, non-smooth, and non-continuous function. It is one of the most complex problems of power systems because it is requires the simultaneous minimization of real power losses to reduce the operating cost and improve the voltage profile, and the cost of additional reactive power sources [5].Capacitors are widely installed on Distribution systems for reactive power compensation to improve the voltage profile and to reduce power and energy losses in the system. The extent of these benefits depends upon how the capacitors are placed in the network and how effective the control schemes designed for them are. The general capacitor placement problem consists of determining the optimal number location, types, and sizes of new and existing capacitors and their control schemes, such that objective function (savings associated with the capacitor placement minus the cost of capacitors)is maximized while the load and operation constraints (voltage magnitude, current flow rating, etc)at different load levels are satisfied.[6]

III. REACTIVE POWER COMPENSATION PRINCIPLES

In a linear circuit, the reactive power is defined as the ac component of the instantaneous power, with a frequency equal to 100/120 Hz in a 50- or 60-Hz system. The reactive power generated by the ac power source is stored in a capacitor or a reactor during a quarter of a cycle, and in the next quarter cycle is sent back to the power source. In other words, the reactive power oscillates between the ac source and the capacitor or reactor, and also between them, at a frequency equals to two times the rated value (50 or 60 Hz). For this reason it can be compensated using Var generators, avoiding its circulation between the load (inductive or capacitive) and the source, and therefore improving voltage stability of the power system. Reactive power compensation can be implemented with Var generators connected in parallel or in series.

The principles of both shunt and series reactive power compensation alternatives are described below:

A. Shunt Compensation

Fig. 1 shows the principles and theoretical effects of shunt reactive power compensation in a basic ac system, which comprises a source (V_1), a power line, and a typical inductive load. Fig. 1(a) shows the system without compensation and its associated phasor diagram. In the phasor diagram, the phase angle of the current has been related to the load side, which means that the active current $I_P$is in phase with the load voltage (V_2). Since the load is assumed inductive, it requires reactive power for proper operation and hence, the source must supply it, increasing the current from the generator and through power lines. If reactive power is supplied near the load, the line current can be reduced or minimized, reducing power losses and improving voltage regulation at the load terminals. This can be done in three ways: 1) with a capacitor; 2) with a voltage source; or 3) with a current source. In Fig. 1(b), a current-source device is being used to compensate the reactive component of the load current. As a result, the system voltage regulation is improved and the reactive current component from the source is reduced or almost eliminated.

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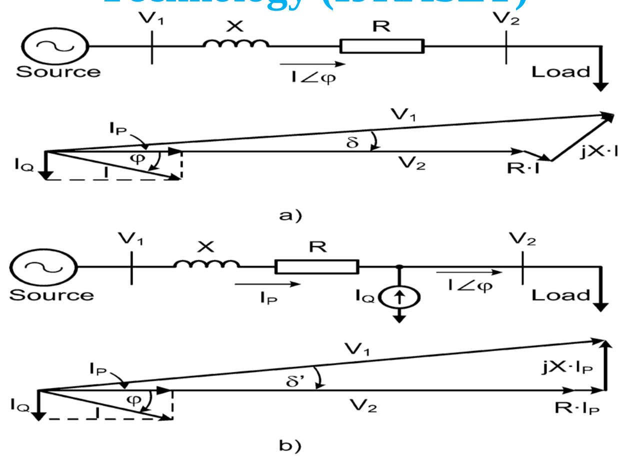


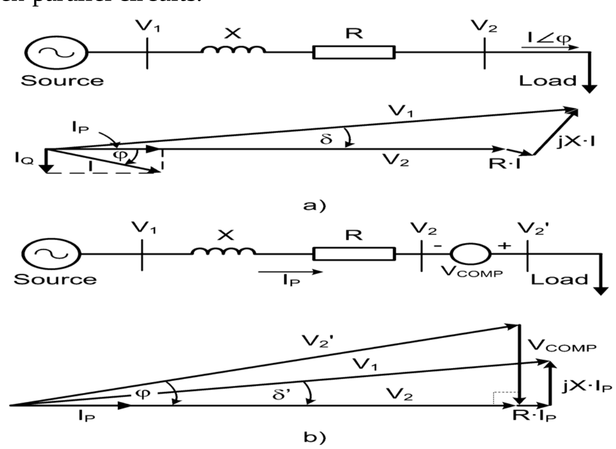
Fig. 1. Principles of shunt compensation in a radial ac system. (a) Without reactive compensation. (b) Shunt compensation with a current source.

If the load needs leading compensation, then an inductor would be required. Also, a current source or a voltage source can be used for inductive shunt compensation. The main advantage of using voltage- or current-source Var genera- tors (instead of inductors or capacitors) is that the reactive power generated is independent of the voltage at the point of connection.

B. Series Compensation

Var compensation can also be of the series type. Typical series compensation systems use capacitors to decrease the equivalent reactance of a power line at rated frequency. The connection of a series capacitor generates reactive power that, in a self-regulated manner, balances a fraction of the line's transfer reactance. The result is improved functionality of the power transmission system through:

1) increased angular stability of the power corridor;
2) improved voltage stability of the corridor;
3) Optimized power sharing between parallel circuits.



Like shunt compensation, series compensation may also be implemented with current- or voltage-source devices, as shown in Fig. 2. Fig. 2(a) shows the same power system of Fig. 1(a), also with the reference angle in V_2, and Fig. 2(b) shows the results obtained with the series compensation through a voltage source, which has been adjusted again to have unity power factor operation at V_2. However, the compensation strategy is different when compared with shunt compensation. In this case, voltage V_{COMP} has been added between the line and the load to change the angle of V_2', which is now the voltage at the load side. With the appropriate magnitude adjustment of V_{COMP}, unity power factor can again be reached at V_2. As can be seen from the phasor diagram of Fig. 2(b), V_{COMP} generates a voltage with opposite direction to the voltage drop in the line inductance because it lags the current I_P.

As was already mentioned, series compensation with capacitors is the most common strategy. Series capacitors are installed in series with a transmission line as shown in Fig. 3, which means that all the equipment must be installed on a platform that is fully insulated for the system voltage (both the terminals are at the line voltage). On this platform, the main capacitor is located together with overvoltage protection circuits. The overvoltage protection is a key design factor as the capacitor bank has to withstand the throughput fault current, even at a severe nearby fault. The primary overvoltage protection typically involves nonlinear metal–oxide varistors, a spark gap, and a fast bypass switch. Secondary protection is achieved with ground mounted electronics acting on signals from optical current transducers in the high-voltage circuit.
Independent of the source type or system configuration, different requirements have to be taken into consideration for a successful operation of Var generators. Some of these requirements are simplicity, controllability, dynamics, cost, reliability, and harmonic distortion. The following sections describe different solutions used for Var generation with their associated principles of operation and compensation characteristics. [7]

IV.STRUCTURE, PRINCIPLE AND SIMULATION MODEL OF THE DC BIAS COMPENSATION DEVICE THAT COMPATIBLE WITH REACTIVE POWER COMPENSATION

A. DC magnetic bias compensation and working principle of the topology that compatibility of *reactive* power compensation.

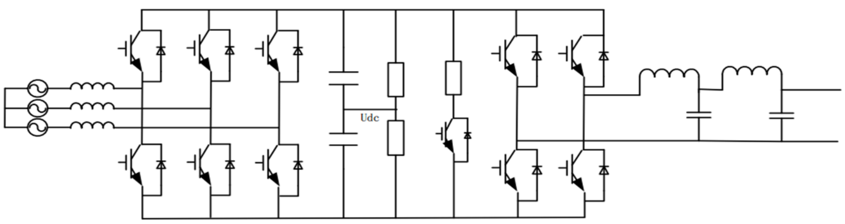


Fig. 2. hybrid structure composed of inverter and chopper

Fig.2 is a hybrid structure composed of inverter and chopper. The left connects to the grid, to produce the required reactive power. While the right side of the chopper device, connects the transformer neutral point to compensate DC magnetic bias. Capacitors in parallel can stabilize the DC side voltage. The two LC filter groups in the right can form a second order filter, which can suppress switching components producing high-order harmonic into the transformer, capacitor C is used to support the voltage.
ASVG is composed of the IGBT, freewheeling diode and capacitor C of voltage supporting.[4]

V. SIMULATION MODEL AND RESULTS

Simulation is done for reactive power compensation. A hybrid system modelling is done by combining the chopper circuit to realize the dual compensation of reactive power and DC magnetic bias, we use the Simulink to run the simulation, its models and results are as follows:

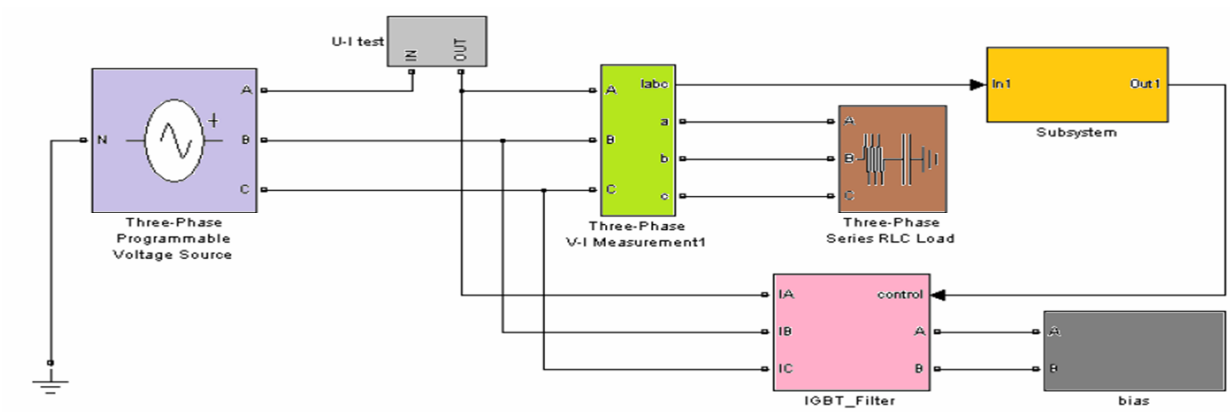


Fig. 3.Simulation Model

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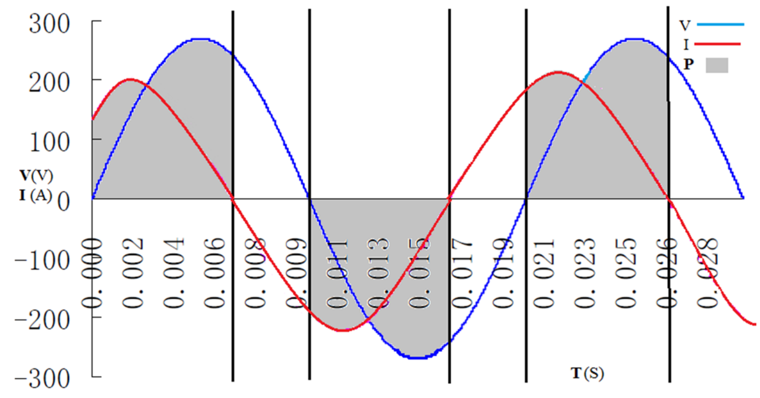

Fig. 4.Graph of phase voltage, current and power without compensation of reactive power

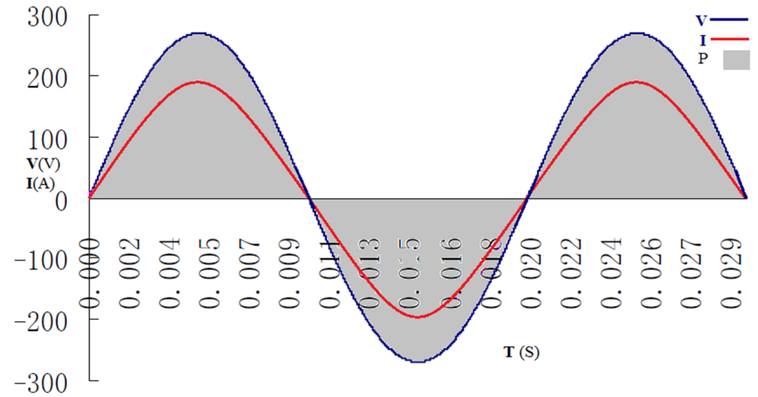

Fig. 5.Graph of phase voltage, current and power with reactive power compensation

VI. CONCLUSION

The results shows that, when we use the compensation device, it can balance the voltage and current to normal levels, as we know that there is reactive power due to capacitive and inductive elements in the grid which can make the current and voltage phase difference, due to which the real power in the system reduces from the ideal level, but after we introduce the compensation device, the current and voltage waveforms have same phase, and due to this compensation effect, power in the system achieves to the desired value with stable voltage.

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