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# ENHANCEMENT OF ACTIVE POWER FLOW CAPACITY OF A TRANSMISSION LINE USING STATCOM MODEL

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***Abstract*— Today the transmission line has many important considerations such as voltage drop, line losses and efficiency of transmission, which is needed to be taken into consideration. A voltage drop of the transmission line is totally depending on resistance and inductance of transmission line. The overall resistance of transmission line causes the power loss. STATCOM is a device which is used for to control the voltage regulation of the transmission line. Static compensation is the solution on voltage drop and power factor reduction. STATCOM uses force commutating devices like IGBT or MOSFET to control reactive power flow through a power network so that it increases stability of the power network.**

***Keywords*—** STATCOM, IGBT, MOSFET.

## I. INTRODUCTION

In transmission line many important considerations such as voltage drop, line losses and efficiency of transmission needed to be taken into account. The values of voltage drop, line losses and efficiency of transmission are gradually influenced by the line constants, these are resistor, capacitor and inductor (R, C, L) of the transmission line. A voltage drop of the transmission line is totally depending on resistance and inductance of transmission line, so the total resistance of the transmission line causes the power loss. While studying the performance of a transmission line it is important to determine voltage regulation and transmission efficiency.

STATCOM is a device which is used for the purpose of voltage regulation of the transmission line and this is a part of the FACTS (Flexible AC Transmission System) [7]. The transmission line has two sides that are a sending side and a receiving side. Both sides have different voltages with respect to source voltage (Vs) and receiving voltage (Vr). The sending end voltages have the unity power factor, but the receiving power factor is 0.8 that happens only because of the load which is connected at the receiving end. At the 0.8 power factor, there is the 80% of real power and 20% is the reactive power. Real power is useful for doing work such as running motors and lightning lamps, but the reactive power is used to magnetize the circuit which in turn supports the voltage that must be controlled for the system's reliability.

The actual power factor of the line is unity, but it is reduced by connecting the load at the receiving end. This load is the inductive load which is connected in parallel to transmission line so that the inductive reactance of the load side is increased and this inductive reactance increases the reactive power so the power factor of a transmission line decreases and voltage drop that occurs. So, this inductive reactance is reduced by using the shunt capacitance. This can be achieved by two techniques which are SVC and STATCOM. For the solution on the voltage drop and power factor reduction, we use STATCOM (Static Synchronous Compensator). It uses force commutating devices like IGBT and GTO to control reactive power flow through a power network so that it increases the stability of the power network. The word synchronous in STATCOM means that it can either absorb or generate reactive power in synchronization with the demand or load of the receiving end to stabilize the voltage of transmission line.

## II. RELATED WORK

Jitendra Kumar, Premalata Jena explained the direction of different types of faults identified using a directional scheme in the presence of STATCOM during SPT. Phase change between positive sequence fault and pre-fault apparent powers are calculated at relay location and are used to define this directional scheme. The technique proposed in the paper was tested for various fault situations by taking into account single and double circuit lines.

During SPT condition, in the presence of STATCOM at different locations for single and double circuit line decision of directional relay was studied [1].

Arvind R. Singh, Nita R. Patne, Vijay S. Kale, Piyush Khadke presented the technique Digital Impedance Pilot Relaying [DIPR] proposed for computation of absolute value of the ratio of the estimated phasor sum of voltages to the phasor sum of currents. This technique is used to differentiate internal-external faults. The terminal voltages and currents of STATCOM impedance variation and bus voltage having high value. This proposed technical plays important role for STATCOM compensated TL and its accuracy is validated using PSCAD EMTDC and using hardware in offline mode [2].

Mohamed Elsamahy, Sherif Omar Faried, Tarlochan Sidhu proposed that midpoint STATCOM has an adverse effect on the performance of the relay. The paper also discusses the coordination between the generator LOE protection and generator under-excited thermal capability limit. It investigates the impact of the STATCOM on coordination through several time domain simulations. This provides accurate evaluations of relay performance, which measured by the relay with absence and presence of midpoint STATCOM. This evaluates the impact of STATCOM on healthy parallel generator [3].

Abayomi A. Adebiyi, K. T. Akindeji explained the effect of Static Synchronous Compensator to mitigate power loss and enhance voltage stability of the transmission system. To validate this capacity of the STATCOM scaled model of bus test was built. A power flow using Newton Raphson algorithms was adapted with and without STATCOM incorporated in power systems. It concludes that there was an improvement in new voltage obtained for weak buses. Also, the active and reactive power losses were mitigated when STATCOM was incorporated at normal load [4].

Ingrole Vinayak K., Awati Nikhil P. represented the MSC-TCR scheme of shunt compensation used in FACTS. The way to compensate for reactive power explained in this paper is Static VAR Compensator (SVC). SVC is crucial for future power to gain how SVC operates. The SVC is also capable of enhancing the active power flow capacity of the transmission line, allows the use of transmission line to maximize power transfer capacity. Also, this technique maintains voltage stability [5].

## III. SYSTEM DESCRIPTION

Fig1 shows the voltage regulating system of the transmission line by using the STATCOM. This STATCOM is the shunt connecting capacitive device so it is connected in shunt of the transmission line. It uses force commutating devices just like IGBT and MOSFET. These MOSFETs are used in the inverter for the voltage source conversion from DC to AC. The inverter circuit consists of MOSFETs so that they require gate triggering. This gate triggering is generated by SPWM circuit otherwise controller circuit.

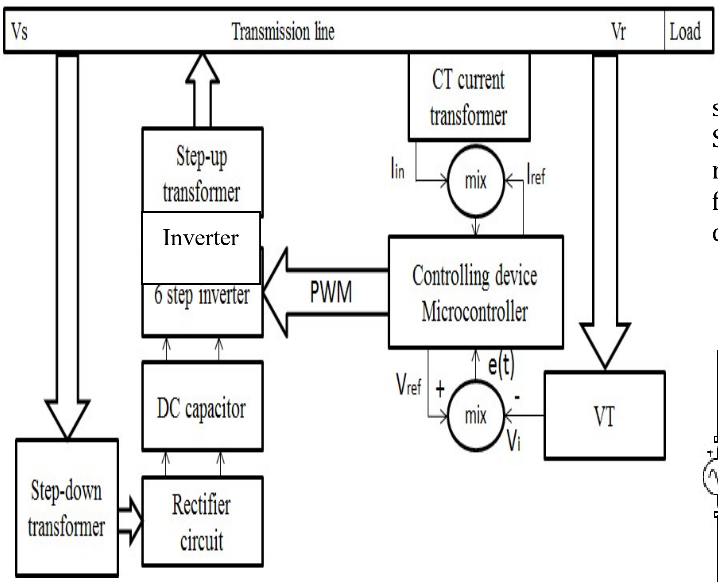


Fig.1 - Proposed Block Diagram

Input of the controller is the receiving side current and voltage. This controller generates the reference voltage and current to find out the error between actual voltage and reference voltage. According to this error signal, the controller generates the PWM signal for the force commutating device. This controller generates different PWM signals according to different type of error occurred. This STATCOM operates when the line voltage is minimum or maximum than the reference voltage that means if $V_i = V_{ref}$ then STATCOM in OFF state, the second is if $V_i < V_{ref}$ and $V_i > V_{ref}$ then STATCOM is in ON state. This STATCOM can restore the voltage of transmission line in fewer cycles.

The actual work of this project is to control the voltage regulation of transmission line. This voltage regulation occurs because of receiving side connected to load and line impedance. If the load is increased then line voltage decreases and at no load condition in line voltage increases. This increase in voltage can cause damage to various appliances. So, to avoid this damage we use STATCOM.

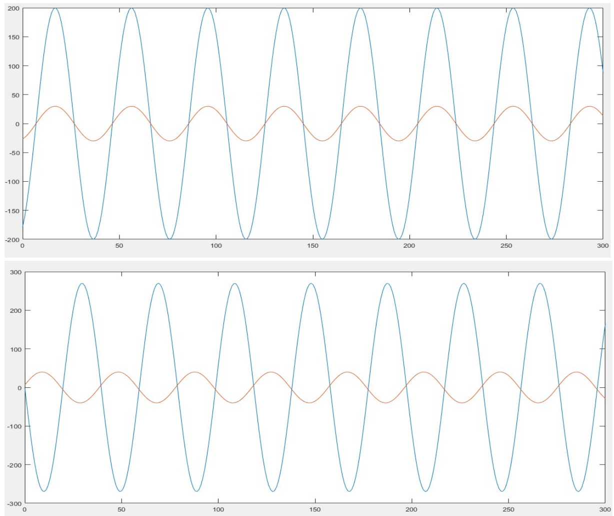

Fig.2 - No load condition and load condition.

At the no load condition line voltage increases, it is shown in fig.2 for that condition the inverter of the STATCOM feeds positive voltage to the line. When we get more voltage than the required at that time inverter will feed negative voltage to line and vice-versa for full load condition.

## IV. TRANSMISSION LINE

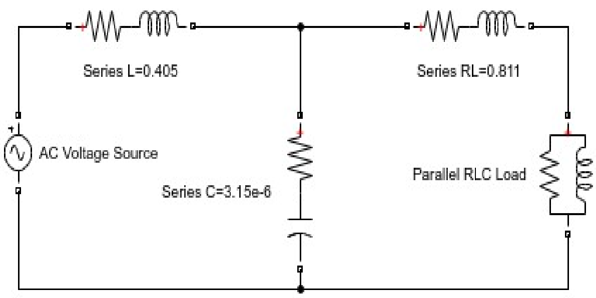


Fig.3- Transmission line model.

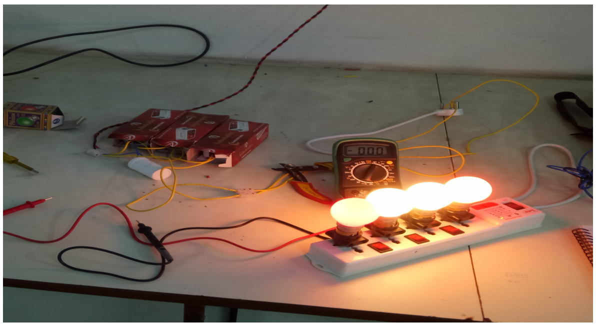

Fig.4- working model of transmission line.

TABLE.1 Results of transmission line.

| Input Voltage in Volt | Line output Voltage at load | Load in Watt | Current in Amp |
|---|---|---|---|
| 250 | 311 | 0 | 0 |
| 250 | 293 | 10 | 0.031 |
| 250 | 273 | 20 | 0.0732 |
| 250 | 255 | 30 | 0.1176 |
| 250 | 234 | 40 | 0.1709 |
| 250 | 203 | 50 | 0.2463 |
| 250 | 184 | 60 | 0.3260 |
| 250 | 166 | 70 | 0.4216 |
| 250 | 114 | 100 | 0.8771 |
| 250 | 273 | 20 | 0.0732 |

## V. SPWM GENERATION

In this project SPWM inverter circuit used. Reason of design SPWM is not just for triggering but also used as a reference signal of transmission line.

SPWM circuit contains the three main components this are Op-Amp, sampling circuit and inversion circuit.

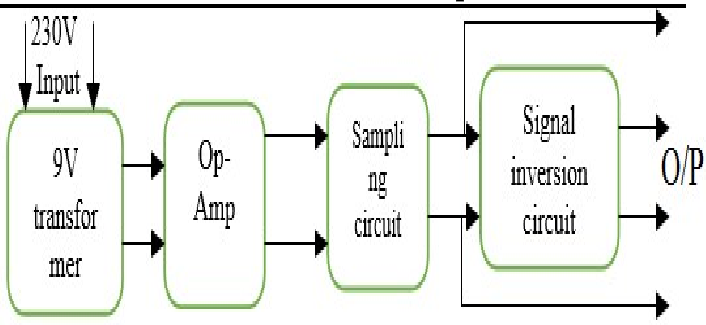


Fig.5- SPWM circuit block diagram.

Op-amp circuit contains six op-amps. Basically op-amp used as the amplifier circuit with high gain, but in this SPWM circuit, we are using the unity gain op-amp configuration. Also, op-amp circuit contains precision amplifier configuration for half wave rectification.

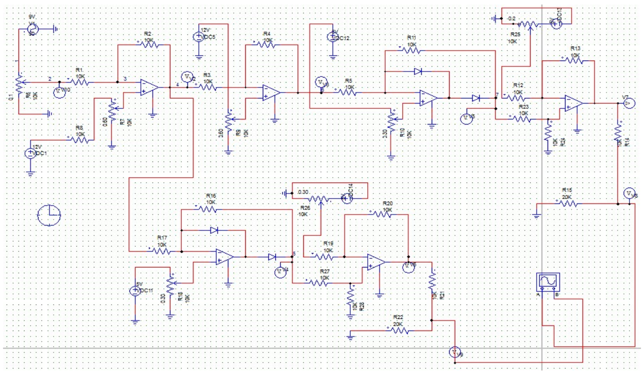

Fig.6- Op-amp circuit section.

The main task of op-amp circuit is to convert full sine wave signal into the two-half wave signal at positive polarity [6]. First op-amp is a unity gain inverting amplifier or comparator. This op-amp inverts the sine wave and control a DC level of cosine wave. Then this DC level shifted cosine wave is given to the precision amplifier as well as an inverting amplifier circuit.

The second inverting amplifier circuit is used for the conversion of the cosine wave to original sine wave with DC level shift. This DC level shifted sine wave is given to the precision amplifier for the half wave rectification. This precision amplifier is working at positive half cycle because of a diode configuration which is in the forward direction, so that the output of this amplifier is a positive half wave. This same working of second precision amplifier. Then this both precision amplifier output is fed to two different subtractor. This subtractor subtracts DC signal from an input signal which is connected at the non-inverting terminal. This DC level subtraction is important for half wave signal down shifting. After this op-amp circuit, we get two half wave signals with 50Hz frequency. This both signals are passed to the next section which is known as sampling circuit.

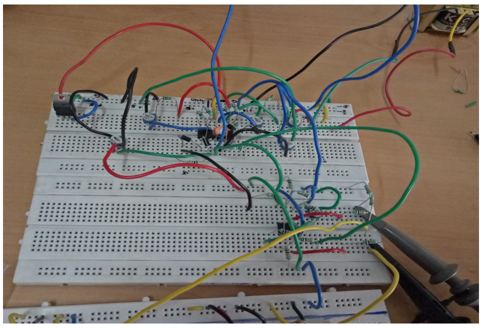

Fig.6a- Op-amp circuit section hardware.

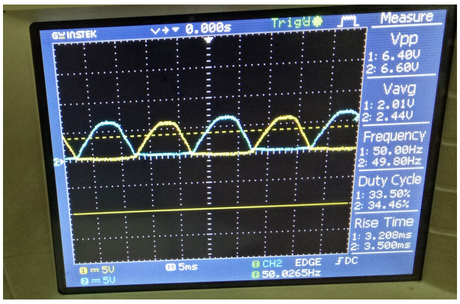


Fig.6b- Op-amp circuit result.

Fig.6b shows the result of the op-amp section. The blue colour waveform shows the first output of the op-amp circuit and yellow colour waveform shows the second waveform of the op-amp circuit. Both these signal results are half wave at the frequency of 50Hz and also the peak voltage of these resultant waveform is same. The DC level of this signal is zero, which is perfect for the sampling.

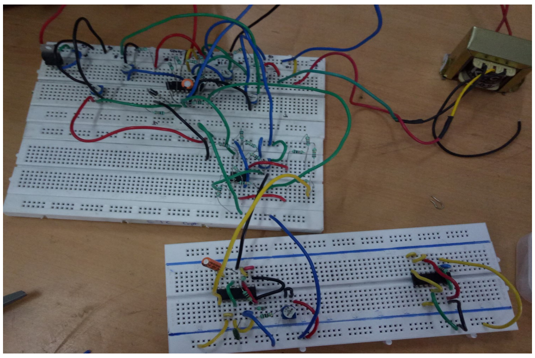

Fig.7- Sampling circuit using TL494.

Sampling circuit contains IC TL494. This IC generates the sampling triangular wave at the frequency range of 10KHz to 300KHz. This frequency is depending on CT and RT of the oscillator pin number 5 and 6. In this project we are sampling our half wave signal at 50KHz frequency, which shows in fig8

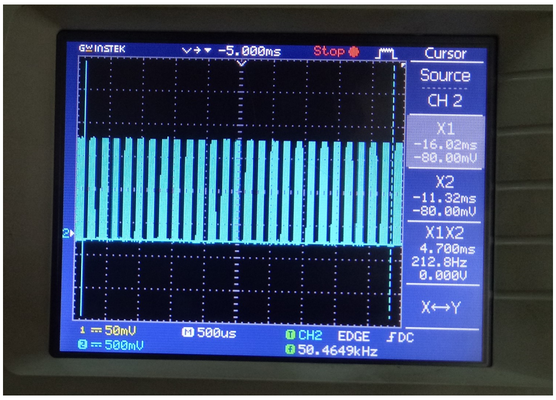


Fig.8- SPWM signal.

After this sampling process, we get two outputs which are applicable of only two MOSFET triggering, but this is not sufficient to drive inverter bridge. So, we take the invention of this both signal by using NOT gate IC for another two MOSFET triggering.

For MOSFET triggering we require the driver IC IR2110. Which having the inputs is HIN and LIN. This HIN is the output signal of TL494 IC and LIN is the inverted signal of this IC output. In this project two IR2110 IC used to drive the four MOSFETs. The first IC drives the 1st and the 4th number MOSFET and second IC drives the 2nd and 3rd number MOSFET.

## VI. SIMULATION OF SPWM IN MATLAB

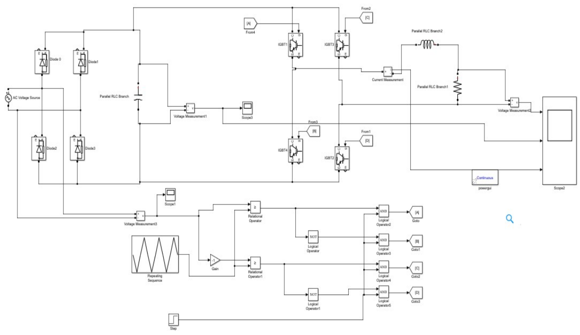

Fig.9- SPWM inverter in MATLAB.

Fig9 shows the SPWM controlled inverter circuit. In this simulation three stages are shown this are converter, inverter and sine PWM generator circuits. Simulation of SPWM inverter is done in MATLAB Simulink software.

SPWM inverter is made to synchronize with an input sine wave.

For the SPWM generation, we take the sine wave. This sine wave is compared with the triangular wave which having the frequency of 50KHZ. Then this signal is multiplied with ramp signal for positive half cycle and negative half cycle. At the positive half cycle T1 and T4 will be ON and in negative half cycle T2 and T3 will be ON. The ON and OFF period of this both half cycles is a 0.01 sec individually.

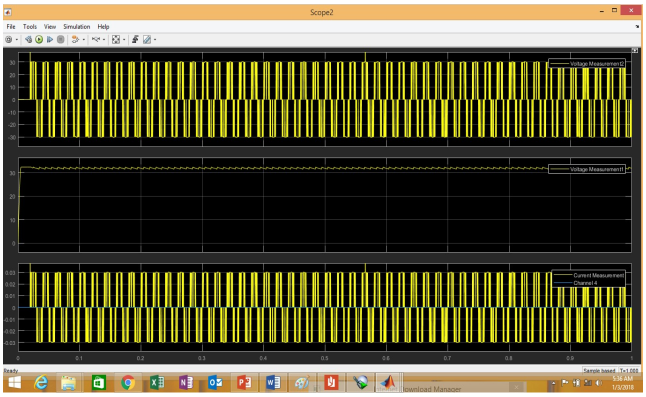

Fig.10- SPWM inverter results

For the SPWM generation, we take the sine wave. This sine wave is compared with a triangular wave which has the frequency of 50KHZ. Then this signal is multiplied with ramp signal for the positive half cycle and negative half cycle. At the positive half cycle inverter T1 and T4 will be ON and in the negative half cycle, T2 and T3 will be ON [8]. The ON and OFF period of this both half cycles is 0.01sec individually this all shows in fig10.

## VII.SIMULATION OF STATCOM

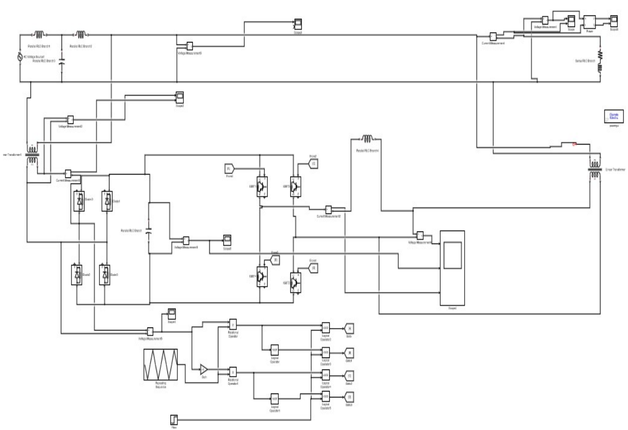

Fig.11- Simulation of STATCOM.

Fig.11 shows the simulation circuit diagram of STATCOM. This simulation shows the feedback based STATCOM with SPWM inverter. By using this circuit, we got approximate results but it requires more accurate result than this. To obtain these results the fluctuation in inverter output current must be reduced.

## VIII. STATCOM SIMULATION RESULTS

The STATCOM simulation result is shown in Fig12 'b' and 'c'. Fig12a shows the transmission line voltage and also known as a reference signal for this system.

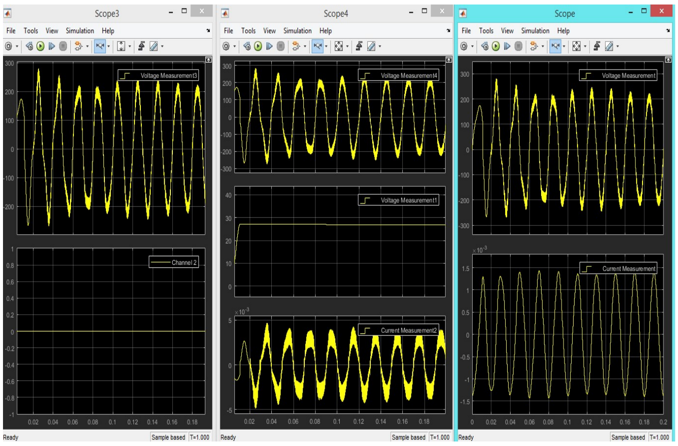

Fig12- STATCOM simulation results a) line voltage.
b) inverter voltage and current c) receiving side line voltage and current

By using this reference signal, we generate the PWM signal, which is known as SPWM. This SPWM signal and inverter output is shown in fig8, but the output of this inverter is not like the sine wave so we use the filter circuit for obtaining the original sine wave. This inverter output is shown in fig12b which is similar in nature of transmission line. Then this inverter signal is given to the transmission line by using a transformer. Then we measure the voltage of the transmission line at the receiving end, which is shown in fig12c.

## CONCLUSION

In this paper, active power flow of transmission line is obtained by controlling the load and source voltage. This controlling is done by STATCOM. The implementation of STATCOM method controls the voltage regulation, increases the quality of power and reduces the power loss.

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