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Ferranti Effect Compensation using TCR with PI Controller

[1] Swati Maruti Wandare [2] Shubhangi Laxman Patankar [3]Shital Ashok Shivasharan
[1][2] UG Student’s,
Department of Electrical Engineering, Rajarambapu Institute of Technology, Islampur (415 414)

Abstract:-- **Applications of FACTS devices for line flow controls, active and reactive power flow controls, loss component control, flexibility in operation & control. To reduce this power quality problems of distribution system, there are no. of power quality solutions techniques by using FACTS controllers, by use of new available power electronics devices. There are no. of factors affect the over voltage. This is effect, which is the voltage value at receiving end of lines is greater than giving point. This occurs because of capacitance charging current resulting over voltage increase with respect to the increase line length. The project is design to implement FACTS with TCR (Thyristor Controlled Reactance).This method is used if low load is there or no load. Because of this, very low flow o current through line and shunt capacitance become dominant. This causes Ferranti Effect, that means receiving end voltage value may be becomes greater than sending voltage (generally for very long transmission lines). To reduce that effect, inductors are automatically connected across line.**

Keywords:— **TCR (Thyristor Controlled Reactor), PI controller, Ferranti effect, Ziegler Nicholas method**

I. INTRODUCTION

From some decades, power systems have a continuous increase in power require without a matching growth of transmission and generation facility. Global transmission system is continuous changing due to steady rise in demand for electricity, mostly of which has to be transmitted a long distance. It's not easy to place an additional plant for power generation to meet the load. However some are short methods to meet the demand, in which the transmission connections are able to take advantages of matching of loads, availability of new sources in order to supplying at minimum cost with Flexible AC Transmission System offer much benefits to system. Applications of FACTS devices for line flow controls, active and reactive power flow controls, loss component control, flexibility in operation & control. To reduce this power quality problems of distribution system, there are no. of power quality solutions techniques by using FACTS controllers, by use of new available power electronics devices.

There are no. of factors affect the over voltage. This is effect, which is the voltage value at receiving end of lines is greater than giving point. This occurs because of capacitance charging current resulting over voltage increase with respect to the increase line length. The project is design to implement FACTS with TCR (Thyristor Controlled Reactance).This method is used, if low load is there or no load. Because of this, very low flow o current through line and shunt capacitance become dominant. This causes Ferranti Effect, that means receiving end voltage value may be becomes greater than sending voltage (generally for very long transmission lines). To reduce that effect, inductors are automatically connected across line.

II. OVERVIEW OF FERRANTI EFFECT

The long transmissions line draws charging current. If that lines are open circuit / low loaded at the end point, the voltage at end may becomes greater than voltage at power giving end, this effect is called as Ferranti Effect.

Causes of Ferranti Effect-

1. Ferranti effect is because of potential drop at the conductor L is in phase with power giving end voltage.
2. Long transmissions line draws charging of capacitance which is produce between line and earth with air as dielectric material. Therefore, C & L is cause for this effect. The capacitance is not considered in less length line and sufficient in medium & long length lines. With help of π model, we can observe Ferranti effect.

Ferranti effect is proportional to square of length of line,
$2\ kx\ V\Delta\propto$
Here, x = length of lines

k = constant

Effects of Ferranti effect on system-

a. Receiving voltage is approximately double of sending end voltage

b. Which causes insulation failure

III. MATHEMATICAL MODELING OF FERRANTI EFFECT

Practically, capacitance of transmission lines is not considered at particular point that is it is uniformly distributed over the complete length of the transmission line. Due to this line charged capacitances this effect is occurs at no load or very light load condition.

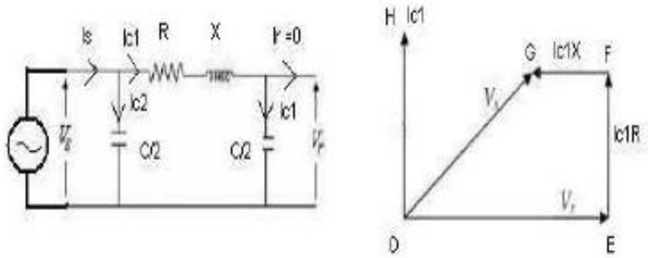

Fig. 1. Nominal π model of the line at no load 2. Phasor diagram For a long transmission line,

Series Impedance Of The Line

$$Z = R + jX$$

Shunt admittance of the line c

$$Y = j\omega c$$

By ohms law,

$$I = \frac{V}{Z} = \frac{Y}{2} V_r$$

By KCL;

$$I_{c1} = I_r + I_{cl}$$

But;

$$I_{c1} = V_r \frac{Y}{2}$$

Then;

$$I_{c1} = I_r + V_r \frac{Y}{2}$$

By KVL;

$$V_S = V_r + I_{c1} Z$$

By putting value of Ic1;

$$V_S = V_r + \left(\tfrac{Y}{2} V_r + I_r\right) Z$$

While simplifying;

$$V_S = V_r + \frac{YZ}{2} V_r + Z I_r$$

$$V_S = \left(\tfrac{YZ}{2} + 1\right) V_r + Z I_r$$

If there is no load condition,

$$I_r = 0$$

$$V_S = \left(\tfrac{YZ}{2} + 1\right) V_r$$

$$V_S - V_r = \left(\tfrac{YZ}{2} + 1\right) V_r$$

$$Vs - Vr = \left(\frac{ZY}{2}\right) Vr$$

But, $z = (r + j\omega l)s$

$$Y = (j\omega c)s$$

If, R of the conductor is neglect,

$$z = (j\omega l)s$$

$$Vs - Vr = \frac{1}{2}(j\omega ls)(j\omega cs)Vr$$

$$= \frac{1}{2}(\omega\text{^}2s\text{^}2)lc$$

So, $Vrnl > Vs$

At no load for transmission line,

$\frac{1}{\sqrt{(LC)}} =$ **Velocity of electromagnetic waves on line = 3*10^8 m/s**

$$Vs - Vr = \frac{-1}{2}(2\pi f)\text{^}2s\text{^}2 \times \frac{1}{(3 \times 108)\text{^}2} Vr$$

By eq., $(Vs - Vr)$ **is - ve,**

That is,

$$Vr > Vs$$

$$= -\left(\frac{4\pi^{\wedge}2}{18\times1016}\right)f^{\wedge}2s^{\wedge}2\times Vr$$

$$Vs = \mathrm{A}Vr + \mathrm{B}Ir$$

$$Ir = 0$$

$$Vr = Vrnl,$$

By above eq., this effect depends upon f & x. Diameter of line & spacing has no cause on Ferranti effect. Generally,

$$Vs = \mathrm{A}Vrnl, |Vrnl| = |Vs| / |\mathrm{A}|$$

whereas,

$$\mathrm{A} = \frac{Vs}{Vr} \text{ (voltage ratio);}$$

$$\mathrm{B} = \frac{Vs}{Ir} \text{ (short circuit resistance);}$$

$$C = \frac{Is}{Vr} \text{ (open circuit conductance);}$$

$$D = \frac{Is}{Ir} \text{ (current ratio);}$$

IV. OVERVIEW OF VARIOUS COMPENSATION METHODS

There are some methods to meet the demand. FACT's gives lot of potential benefits to power system. Such applications of FACT's devices are line flow control, active& reactive power flow controls, loss minimizations, flexibility in operation & control. To reduce the power quality problem of systems, we have number of power quality solutions techniques by using FACT's controllers, with the use of power electronics devices.

Types-

1. Shunt compensation
2. Series compensation
3. Combined compensation
a. Series-series compensation
b. Series-shunt compensation
Shunt compensation-

1. Shunt capacitance compensation-

Shunt compensation fashion is useful to improve p f of system. Generally for L load the I lag the V, by which pf is lagging. To compensate this shunt capacitor is use, to draw the leading the current than voltage value. The result is improving pf.

2. Shunt reactor compensation-

Shunt inductive compensation fashion is useful at no load / less load at end of lines. Due to which, less amount of flow of current through lines & result in Ferranti Effect. I.e. Vr = 2Vs. For to compensate this one a shunt inductor are connected across the line. Series compensation- The series controllers may be capacitor, reactors etc. These series controllers are inserting in transmission line in order to inject the voltage in series to line. Combined compensation- For some applications combined compensators i.e. two compensators are injected to line. TCR (Thyristor controlled reactor)- Thyristor controlled reactor consist of a fixed value reactor & 2 antiparallel SCRs. By using Gate pulses control of SCRs, we can control effective value of reactor. & also this block instantly after alternating I cross zero point. I flows through L can control from max. (Scr close) to zero point (silicon controlled rectifier is opened) by firing delay with angle control. That is scr conduction is delay w. r. t. the max. Value of the given voltage for every half cycle of waveform. Thus period of I conduction is control, this is for +ve and –ve cycle to control as fig. b, which shows given voltage v & inductor current IL, for zero α (switch totally close) & at α delay for different angles. At α =0, scr close at crest of V and resultant current in reactor is same as get with permanently closed switch. When the apply gate pulse to scr, it is delayed by angle α ($0 \le \alpha \le \pi/2$) with respect to then crest of the voltage, the current in the reactor will be expressed as follows, V (t) = V cos (ωt)

$$IL = (1/L)\ \alpha \int \omega t\ V(t)\ dt = (V/\omega L)\ (\sin \omega t - \sin \alpha)$$

Therefore, the scr open at current reaches to zero; it is for period $\alpha \le \omega t \le \pi-\alpha$. For -ve half-cycle , the sign of equation becomes opposite. For above equation the term (V/ωL) sin α = 0 is offset which shifted down at +ve and up at -ve current half cycles get at α = 0, as shown in fig.2. So, the scr's get turn off at instant of current zero crossing, this process actually control conduction interval of the SCR. i.e., delay angle α.

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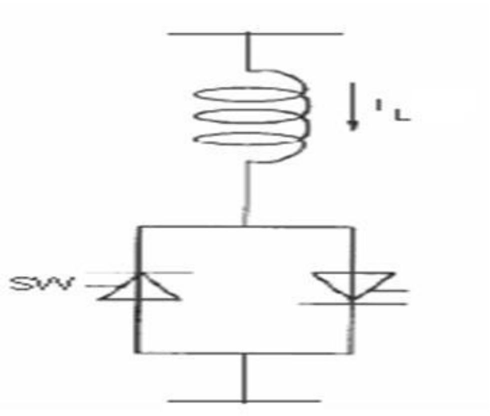


Fig:3 TCR

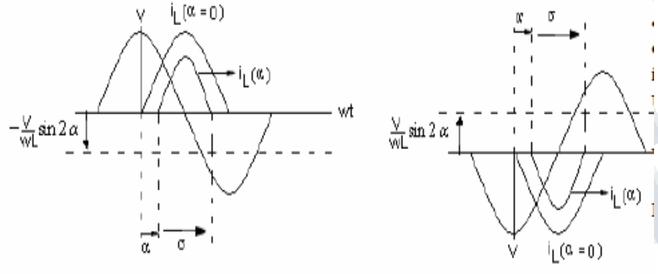


Fig.4 operating waveforms across TCR

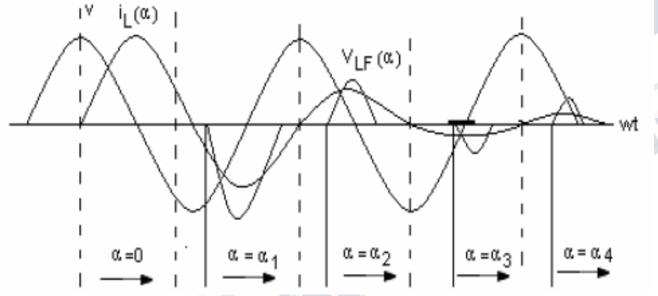


Fig.5 operating waveforms

Reactor-

Importance of reactive power in system- Voltage control in an electrical power system is important for good operation for electrical power equipment to prevent overheating of generators and motors 4.3.3Advantages of TCR-

1. Fast response- With the help of TCR control response get faster than normal system.
2. Fully controllable- By controlling SCR firing angle, we can control current through reactor so, it is fully controllable.
3. No effect on fault level- On full load TCR is acting as opencircuit i.e. On load condition system like without compensator.

4.3.4 Disadvantages of TCR-

1. Increases harmonics
2. Require shunt filter- Due to increase in harmonics, it can be dangerous for system. So, for eliminate we require filters which increase cost.

5 Control Of TCR with PI controller Methods to control TCRBy using Microcontroller-

In this system the lead time within zero V pulse & zero I pulse are generate by right op-amp is given to 2 interrupt pin of μc, at which program is brings the shunt reactors to the circuit to get the voltage compensated. Anti-parallel SCRs and the program of microcontroller are used in series for switching the reactor. By using PI controller- With the help of controllers we can control the value of reactor, which can be controlled by controlling Proportional plus integral controller (PI)-

PI controller is useful to develop industries. Propotional plus integral controller is better solution because it has no complex in construction & in practice. But one difficulty construct it is it require different gain constants for different applications & it is hard to calculate. And also it is more critical if there is error to select constants ,

$$U(s) = Kp*E(s) + Ki*E(s)/s$$

Where, E(s) = error signal
K =Proportional gain constant
Ki =integral gain constant
U(s) =actuating signal By using Zeigler-Nicholas method for tuning (second method) ,we can calculate gains for P and I;
KP=0.9T/L

By above expression we can conclude that, by using PI controller we can control difference between power giving end voltage and receiving end voltage I.e. error(between expected value and actual value)

V. SIMULATION RESULTS

Block diagram for Ferranti effect-

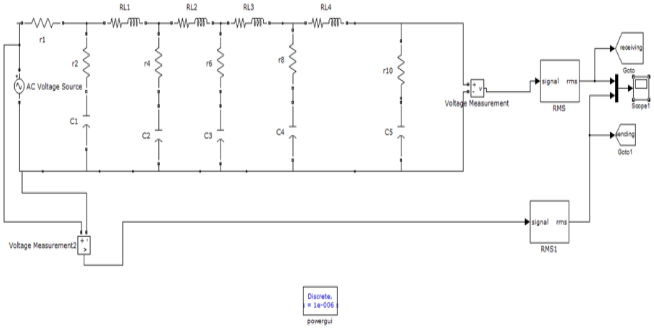


Fig 6: Block diagram for Ferranti effect

Simulation result-

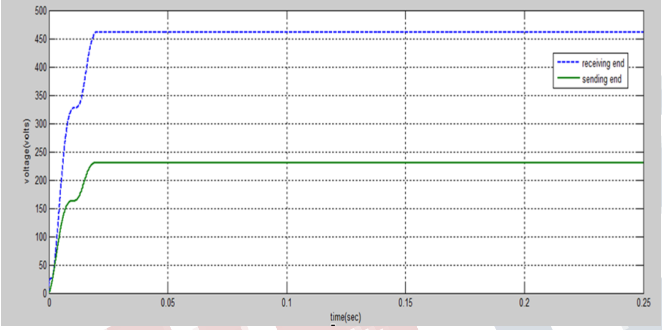


Fig7: Simulation result for Ferranti effect

Due to capacitor charging current voltage at output side get greater as shown in Matlab simulation as above. This is known as Ferranti effect. Block diagram with TCR (open loop) –

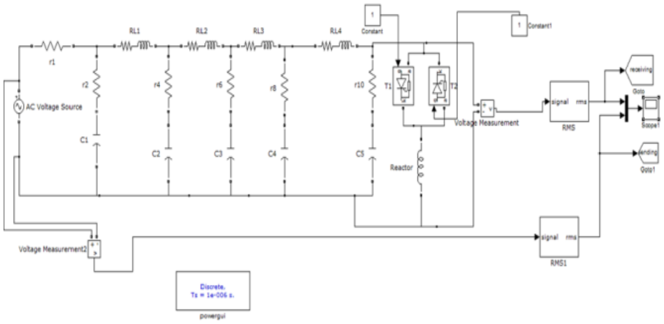
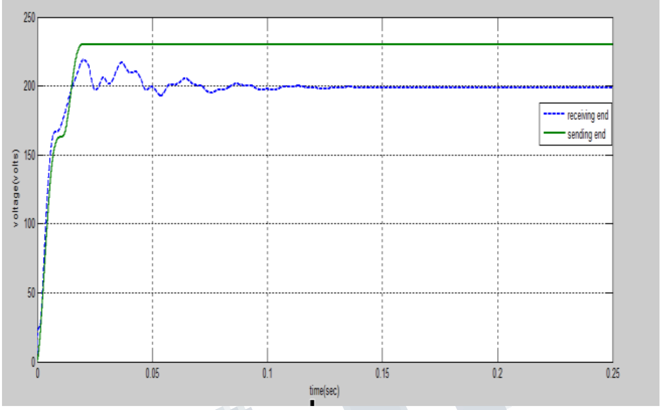


Fig: 8 block diagram with TCR (open loop)

Simulation result-



With adding TCR in system as shown in above simulation result voltage reduces at output side but not exactly equals to sending end voltage.

Block diagram with tsr using PI controller-

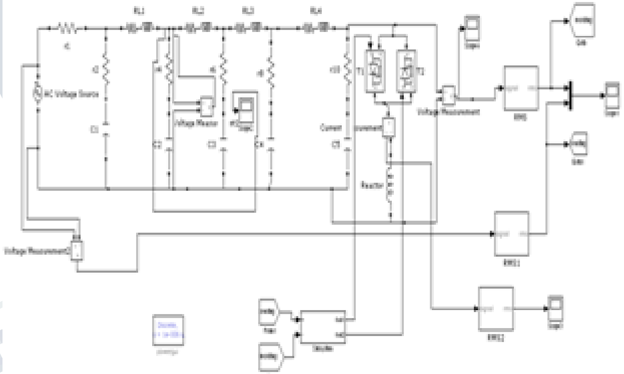


Fig: 10 block diagram with PI controller

Simulation result-

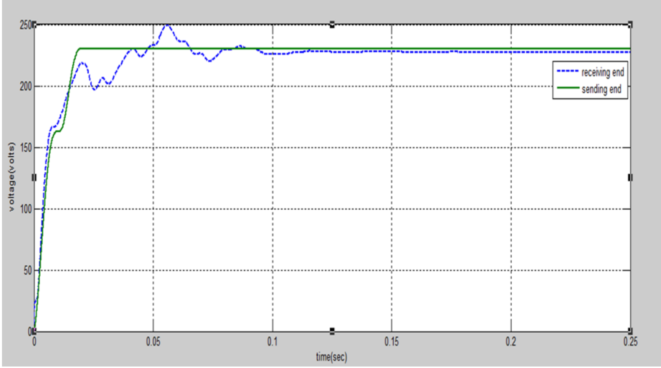


Fig: 11

With the help of PI controller with proper tuning for Proportional and integral gains, we can achieve receiving end voltage nearly equals to sending voltage as shown in fig Voltage across reactor

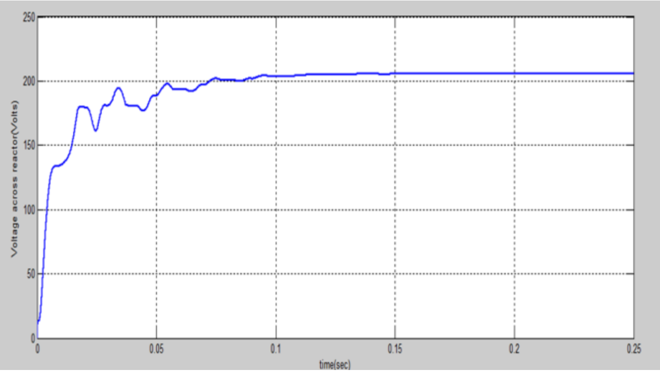


Fig:12 voltage across reactor

Simulation result in comparison format-

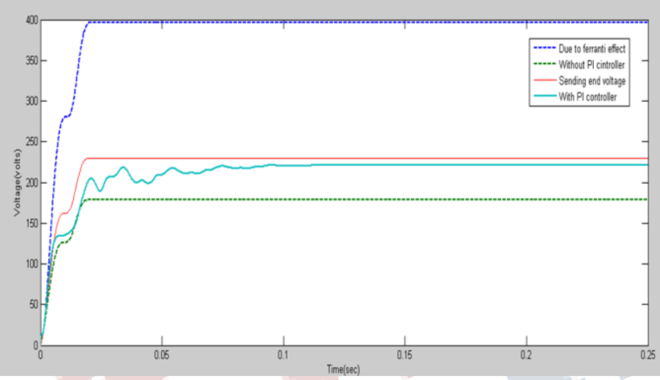


Fig13 : Simulation result in comparison format

VI. CONCLUSION

Due to Ferranti effect, receiving end voltage isapproximately double of value of sending end voltage. As shown in fig. 1 In first response.By TCR use at open loop control system, reactor reduce receiving end voltage. By use of PI controller with closed loop control, by control of gate pulse of SCR automatically get end point voltage is equal to power giving end voltage i.e. Vr = Vs

Future scope

We can improve response of system using advance control techniques, which can more economical and more effective to get sending and receiving end voltage equals.

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1.Swati Maruti Wandare
2.Shubhangi Laxman Patankar
3.Shital Ashok Shivasharan

(Students of Rajarambapu Institute Of Technology, Islampur. Dist- Sangli, Maharashtra) Under guidance of Mr. VRSV Bharath Pulavarthi (M.Tech. in control systems WCE Sangli) Area of interest- Control system. Email ID-bharath.pulavarthi@ritindia.edu and Mr.Namdeo Gujalwar (M Tech in power system IIT, Kharagpur) Email ID-namdeo.gujalwar@gmail.com