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Series Compensated Line Protection using Artificial Neural Network

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Abstract: This paper presents Artificial Neural Networks primarily based protection for series stipendiary lines and also the downside Janus-faced by the space protection theme used for transmission lines protection once they square measure stipendiary serial with the FACTS devices like TCSC. the employment of TCSC creates sure issues to distance protection schemes as there's a modification within the apparent ohmic resistance measured by the relay. The modification within the apparent ohmic resistance measured is corrected by mistreatment Artificial Neural Networks (ANN) for the proper operation of the relay, that is extensively tested mistreatment MATLAB Simulation for various conditions. The results obtained show that by mistreatment the synthetic Neural Networks coaching strategies the operation accuracy of the relay used for distance protection is improved.

Keywords: Artificial Neural Networks, Distance protection, FACTS devices, Thyristor Controlled Series electrical condenser

I. INTRODUCTION

Presently as a result of the liberation of power trade and also the restriction Janus-faced by power trade as a result of energy, environmental and restrictive problems, the most challenge is to enhance the facility transfer capability and conjointly to enhance the system integrity of the given transmission facility. The on top of mentioned downside is self-addressed by mistreatment series compensation. Series compensation once introduced in power systems influences the facility flow during a specific network section that reduces active power losses and conjointly prevents system - sub synchronous oscillations [1]-[3]. FACTS device square measure ordinarily utilized in power systems that takes care of the facility transfer capability, voltage stability and power oscillation damping. Thyristor Controlled Series electrical condenser (TCSC) is one in all the series compensation device used however, the employment of TCSC creates sure issues for standard distance protection schemes as a result of the changes within the apparent ohmic resistance measured by the relay. The apparent ohmic resistance seen by the relay is influenced by the unsure variation of series compensation voltage [4]-[5]. suppliers of transmission facilities ordinarily like distance protection because the primary protection system, As series compensation is introduced in power transmission lines it desires extra attention whereas selecting the protection scheme as series compensation needs further care additionally to the well apprehend protection challenges on HV transmission networks. In fashionable days facility protection systems has become intelligent has it uses microchip primarily based techniques like Artificial Neural Networks to enhance distance protection of line with TCSC compensation that uses back propagation rule and is extensively tested mistreatment MATLAB Simulation for various conditions [6]-[11].

This paper is organized as follows: within the initial section the introduction to Protection of Series stipendiary Transmission Lines mistreatment Artificial Neural Networks is mentioned, within the second section temporary introduction of Thyristor Controlled Series Capacitor(TCSC) is bestowed, within the third section Artificial Neural Networks square measure mentioned, within the fourth section Distance Protection basics and impact of SC Compensation on Protection is bestowed, in fifth section simulation strategies used and results square measure bestowed and in sixth section conclusions supported the results obtained square measure bestowed.

II. THYRISTOR CONTROLLED SERIES CONDENSER

For many years series compensation technique is employed to regulate the facility transfer between 2 stations by adjusting net series ohmic resistance of the road. Installation of a series electrical condenser could be a standard and established technique of skyrocketing line capability, by reducing net series ohmic resistance, so increasing power transmission. As this technique is well established technique however, as a result of the limitation of its slow shift time it's replaced by Thyristor controllers, that square measure quick acting devices as a result of that fast and continuous management of line compensation is feasible. Thyristor Controlled Series electrical condenser (TCSC) is one in all the controllers used for series compensation. TCSC could be a reality device that could be a combination of thyristor-

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controlled reactor (TCR) parallel with electrical condenser. TCR could be a variable inductive reactor XL (α) controlled by firing angle α.

Fig. 1. shows the ohmic resistance graphical record of TCSC versus the firing angle α. From figure we tend to see that each electrical phenomenon and inductive regions square measure potential by varied firing angle (α). In sensible theme, the TCSC is sometimes created with a Metal compound Varistor (MOV) and a bypass switch used as protecting devices, as per Fig. 1 MOV, that could be a nonlinear electrical device, protects the TCSC against high electrical condenser overvoltage by providing a alternate path for the fault current. A breaker is additionally gift across the TCSC to bypass it if a severe fault or instrumentation malfunction happens. there's conjointly provision for a current limiting inductance, Ld, within the breaker branch to limit the electrical condenser current throughout the bypass operation.

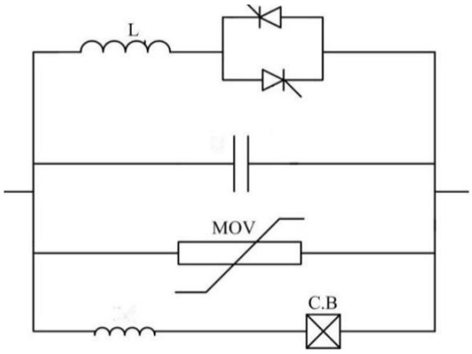

Fig. 1: TCSC circuit configuration

A. Different Modes Of Operation

By dynamic the firing angle of the thyristors the effective electrical phenomenon of the TCR is varied. This variable TCR electrical phenomenon in parallel with a set electrical condenser combination makes the TCSC to work in four totally different modes; interference mode; bypass mode; electrical phenomenon boost mode; and inductive boost mode. Since we tend to have an interest within the downside Janus-faced by the protection theme during this paper we tend to solely take up the electrical phenomenon boost mode that is employed for increasing the facility transfer capability of the actual line section

B. Capacitive Boost Mode

In electrical phenomenon boost mode of operation, a trigger pulse is provided to the thyristor having forward voltage simply before the electrical condenser voltage crosses the zero line, thus an electrical condenser discharge current pulse can flow into through the parallel inductive branch. The discharge current pulse adds to the road current through the electrical condenser and causes a electrical condenser voltage that adds to the voltage caused by the road current. The electrical condenser peak voltage so is multiplied in proportion to the charge that passes through the thyristor branch. the basic voltage conjointly will increase virtually proportionately to the charge. From the system purpose of read, this mode inserts electrical condensers to the road up to just about 3 times the fastened capacitor. this is often the conventional in operation mode of TCSC. By dynamic the firing angle of the thyristors the effective electrical phenomenon of the TCR is varied. This variable TCR electrical phenomenon

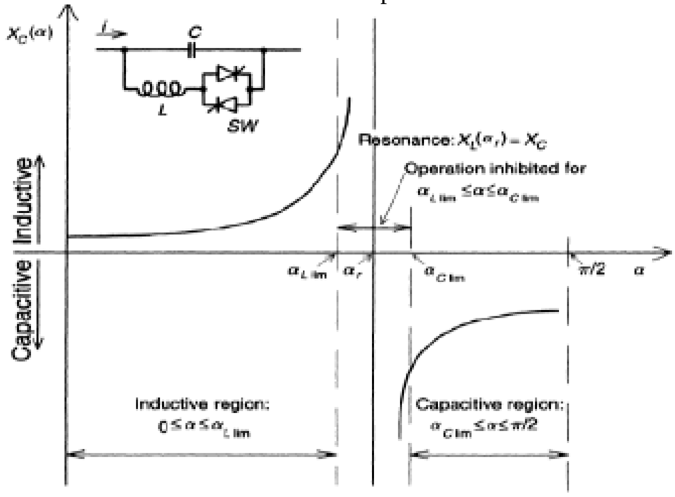

Fig. 2: TCSC electrical phenomenon versus delay angle α

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III. ARITIFICAL NEURAL NETWORKS

An Artificial Neural Network, simply named as Neural Network, could be a mathematical model galvanized by biological neural networks. A neural network consists of associate interconnected cluster of artificial neurons, and it processes data employing a connectionist approach to computation. In most cases a neural network is associate adaptative system dynamic its structure throughout a learning section. Neural networks square measure used for modelling complicated relationships between inputs and outputs or to search out patterns in knowledge. There are

- Modelling
- Foretelling and prediction
- Estimation and management

To train associate ANN mistreatment BP to unravel a selected downside their square measure typically four major steps within the coaching process:

- Step 1- Assemble the acceptable coaching knowledge
- Step 2- produce the network object
- Step 3- Train the network and
- Step 4- Simulate the network response to new inputs.

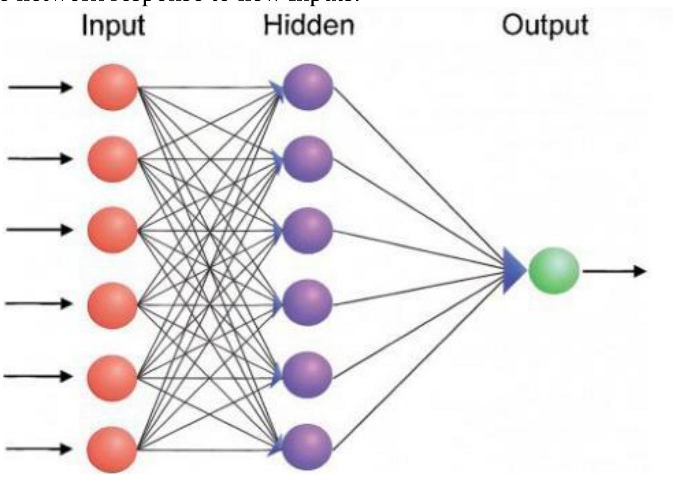

Fig. 3: Design of Artificial Neural Network

IV. DISTANCE PROTECTION BASICS AND EFFECTS OF SC ON PROTECTION

A. Distance Relays

Distance relays, because the name says, measures distance. this is often true just in case of line, as distance relay measures the ohmic resistance between the relay purpose and also the fault location. This ohmic resistance is proportional to the length of the conductor, and thus to the space between the relaying purpose and also the fault [13].

B. Zones of Protection

Basically distance protection has instant directional Zone one protection and one or longer delayed zones. Numerical distance relays consist up to 5 zones, of that some square measure utilized in the reverse direction. the moment Zone I protection setting is up to eighty fifth of the protected line mistreatment Numerical distance relays. The Zone a pair of protection setting ought to be a minimum of a hundred and twentieth of the protected line ohmic resistance. Zone three reach ought to be set to a minimum of one.2 times the ohmic resistance bestowed to the relay for a fault at the remote finish of the second line section [13]. Typical reach for a 3-zone distance protection square measure shown in Fig.4.

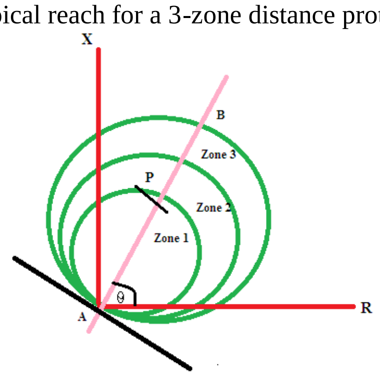

Fig. 4: Typical three zones of distance protection relay wherever AB Protected line θ Line angle AP ohmic resistance setting

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C. Impact of TCSC On Distance Protection

Series compensation mistreatment TCSC plays an important role in loaded transmission lines. The usage of TCSC in transmission networks needs extra studies into the expected performance of the new system and conjointly the influence on the operation of existing protection management and watching systems. as a result of the introduction of series capacitance within the line, the road electrical phenomenon creates issues for the effective operation of ohmic resistance primarily based distance relays. The relays, that build use of ohmic resistance measurements so as to work out the presence and placement of faults, square measure "fooled" by put in series capacitance on the road once the presence or absence of the electrical condenser within the fault circuit isn't acknowledged priori. TCSCs and their overvoltage protection devices (typically Metal compound Varistors (MOVs) and/or air gaps), in spite of their helpful effects on the facility system performance, introduce extra issues and build the in operation conditions unfavourable for the protecting relays that use standard techniques and embrace phenomena like voltage and/or current inversion, sub harmonic oscillations, and extra transients caused by the air gaps triggered by thermal protection of the MOVs. The apparent electrical phenomenon and resistance seen by the relay square measure affected as a result of the variation of series compensation voltage throughout the fault amount.

D. Impact of TCSC On Zones Of Protection For A Distance Relay

Due to the introduction of TCSC the apparent electrical phenomenon and resistance seen by the relay square measure affected as a result of the variation of series compensation voltage throughout the fault amount. as a result of that the traditional relay gets tripped unnecessarily although the fault isn't gift in its zone of protection [3], [5]. Introduction of TCSC ends up in the changes of zones of protection of ordinarily set distance relay used for line protection. Fig.5 shows the zones of protection of a line once TCSC is introduced, and Fig. half-dozen shows the mix of Fig. 4 and Fig. five to urge a transparent understanding of presence of TCSC.

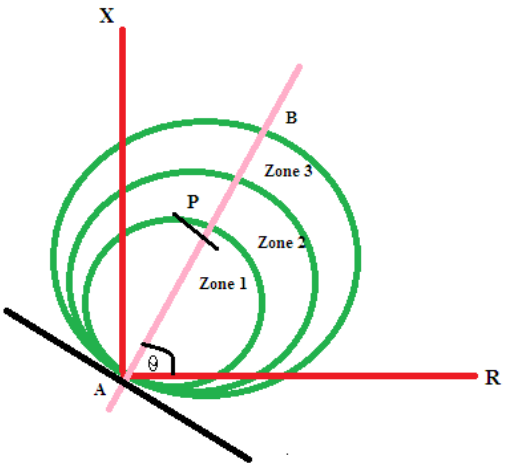

Fig. 5: Zones of protection of a line with TCSC

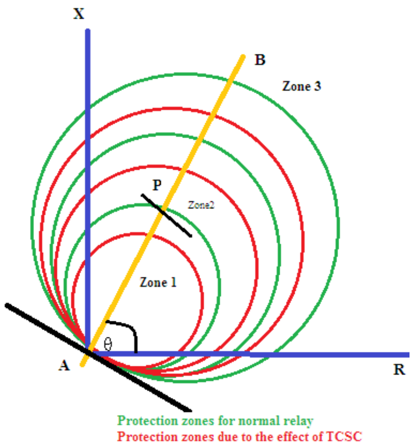

Fig. 6: Combination of Zones of Protection for traditional relay and TCSC operation where AB Protected line θ Line angle AP ohmic resistance setting

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V. SIMULATION AND RESULTS

The take a look at system used for during this paper could be a 500KV, sixty Hertz facility that has 2 sources such as 2 areas joined by a 400km line. during this system the TCSC is placed within the middle of the line as per the only line diagram shown in fig. 7

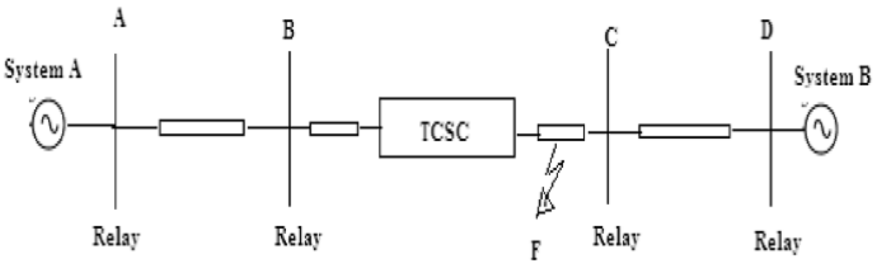

Fig.7: Seven Single-line diagram of the take a look at system

The model shown within the single line diagram is modelled for model in MATLAB/Simulink setting. once the simulation waveforms for various in operation conditions square measure taken Fig. 8 and Fig. nine shows a 3 section voltage and current waveforms while not TCSC within the system. Fig.10 and Fig.11 shows the voltages and current waveforms with TCSC gift within the system. Fig. eleven conjointly shows that whenever a fault happens on the system the fault current will increase short and involves traditional condition once fault is cleared. for various take a look at conditions voltages and current values square measure collected from them, by the assistance of quick analysis tool box gift within the MATLAB tool box the voltages and currents at the relay square measure calculated. primarily based informed the values of voltages and currents at {different|totally totally different|completely different} take a look at conditions and different fault conditions ohmic resistance of that specific line section is calculated and also the results square measure bestowed in table (I).

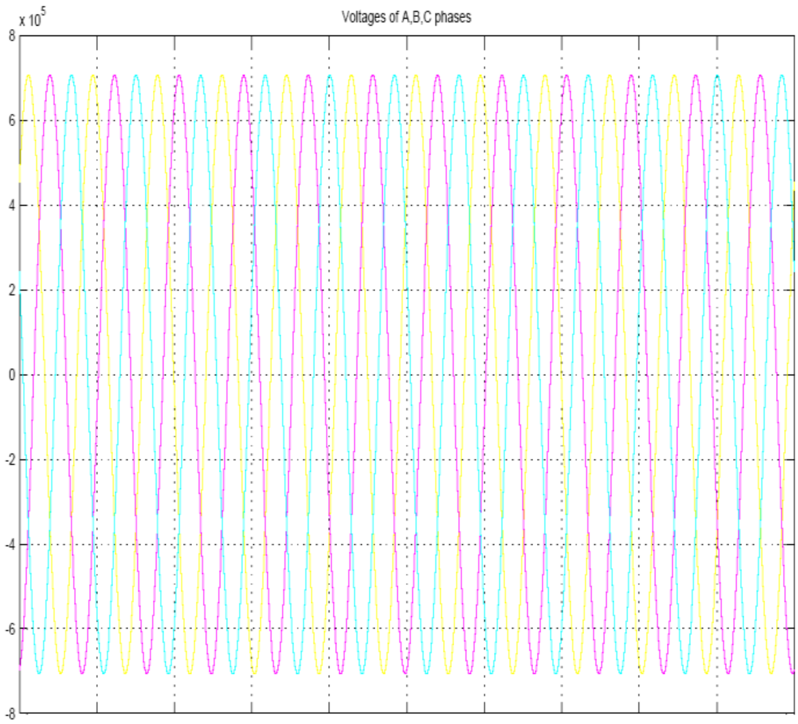

Fig. 8: Voltage waveforms while not TCSC

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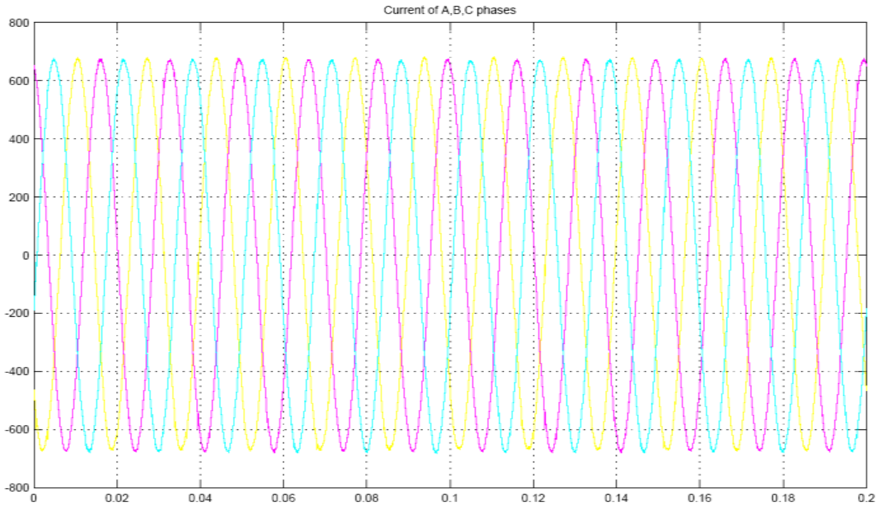

Fig. 9: Current waveforms while not TCSC

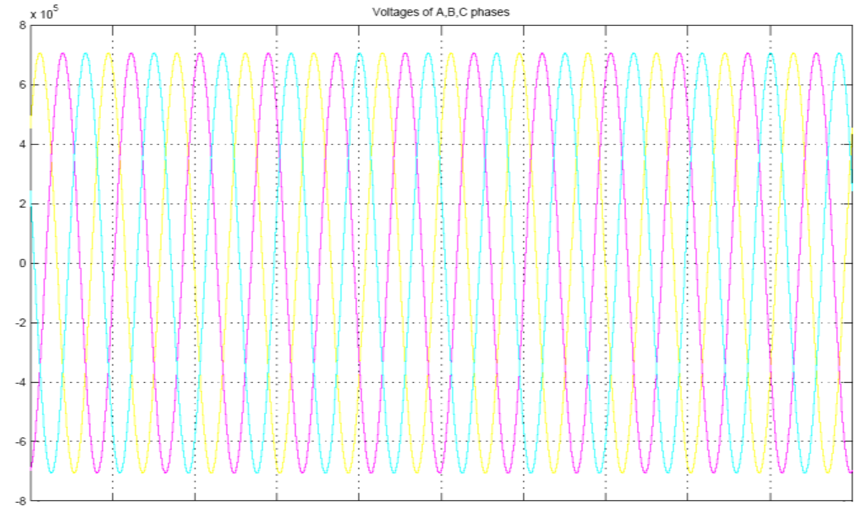

Fig. 10: Voltage waveforms with TCSC in electrical phenomenon mode of operation

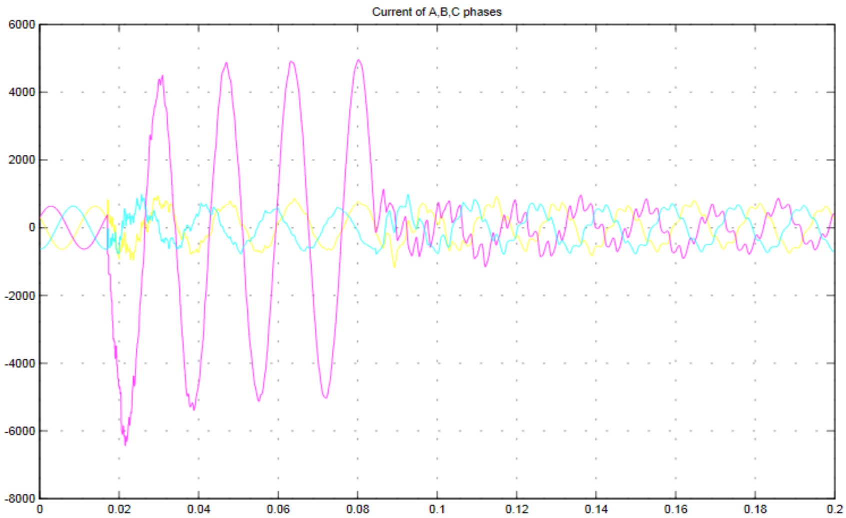

Fig. 11: Current waveforms with TCSC in electrical phenomenon mode of operation

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Table: I. Ohmic resistance values with TCSC within the middle of the road

Type of Fault	Fault Point in % of line	Impendence without TCSC in Ω for different line sections			Impendence with TCSC in Ω for different line sections α = 70°		
		AB	BC	CD	AB	BC	CD
L-L-L Fault	90%	--	112.0274	--	--	61.7669	--
L-L Fault	90%	--	135.2136	--	--	71.7293	--
L-G Fault	90%	--	383.3196	--	--	267.2748	--
L-L-L Fault	85%	54.6938	105.3275	52.1208	52.1317	59.6032	43.1282
L-L Fault	85%	59.8134	126.9644	135.2136	60.3985	69.1844	51.4553
L-G Fault	85%	118.0037	367.1406	407.9256	123.3292	253.9629	336.2055
L-L-L Fault	80%	49.0294	112.0274	51.3222	49.0249	55.8658	40.7595
L-L Fault	80%	56.2036	135.2136	63.9664	56.7585	64.3762	48.8305
L-G Fault	80%	110.6660	383.0049	402.1007	114.7544	230.8609	323.4493
L-L-L Fault	70%	42.8534	105.3259	44.1768	42.8902	53.0622	35.1386
L-L Fault	70%	49.0294	126.9644	55.0764	49.4169	61.9795	41.8215
L-G Fault	70%	96.1361	366.8508	391.3907	99.2852	207.4894	312.2703
L-L-L Fault	60%	36.7180	100.2228	37.4306	36.7180	51.8518	29.6686
L-L Fault	60%	41.8844	120.4284	46.5251	42.2025	60.8375	35.4104
L-G Fault	60%	81.8226	351.0993	379.7783	84.1352	184.615	301.2829
L-L-L Fault	50%	30.5871	92.8484	31.0369	30.5871	52.6750	24.4962
L-L Fault	50%	34.8016	111.2413	38.3350	35.0210	61.9640	29.2040
L-G Fault	50%	67.7183	335.1488	368.2882	69.3043	162.6950	290.0552

Table: II Protection behaviour of the relay within the specific line section

Type of Fault	Fault Point in % of line	Trip/No Trip of the relay based on impendence calculated		
		AB	BC	CD
L-L-L Fault	90%	--	Trip	--
L-L Fault	90%	--	Trip	--
L-G Fault	90%	--	Trip	--
L-L-L Fault	85%	No Trip	Trip	Trip
L-L Fault	85%	No Trip	Trip	Trip
L-G Fault	85%	No Trip	Trip	Trip
L-L-L Fault	80%	Trip	Trip	Trip
L-L Fault	80%	Trip	Trip	Trip
L-G Fault	80%	Trip	Trip	Trip
L-L-L Fault	70%	Trip	Trip	Trip
L-L Fault	70%	Trip	Trip	Trip
L-G Fault	70%	Trip	Trip	Trip
L-L-L Fault	60%	Trip	Trip	Trip
L-L Fault	60%	Trip	Trip	Trip
L-G Fault	60%	Trip	Trip	Trip
L-L-L Fault	50%	Trip	Trip	Trip
L-L Fault	50%	Trip	Trip	Trip
L-G Fault	50%	Trip	Trip	Trip

Based on the results of table (I) the relay gift for defense of that specific zone sends a wrong trip signal that is shown in table (II). As we tend to already mentioned in introduction that as a result of the introduction of TCSC there's a drag for defense circuit that has got to be corrected, this modification in ohmic resistance is corrected with the assistance of Artificial Neural Network. The coaching cases used for the coaching of the ANN square measure generated

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mistreatment MATLAB/Simulink take a look at system shown in fig. seven for numerous types of faults (LLL-Fault, LL-Fault and LG-Fault) fault location (90%, 85%, 80%, 70%, hour and five hundredth length of line) and with totally different firing angles of TCSC (60°, 63°, 65°, 68° and 70°), with all the on top of {different|totally totally different|completely different} coaching cases different coaching vectors were collected at a rate of sixteen samples/cycle. The inputs given for the coaching of ANN square measure voltage, current of the relay location and firing angle at that TCSC is working. The output expected from the ANN system is trip or a no trip signal to the breaker within the sort of [0 zero zero one one one 1]. ANN uses back- propagation rule for its coaching purpose and also the variety of neurons within the hidden layer is set supported the trial and error technique. within the gift downside supported the trial and error technique we tend to come back to the conclusion that with ten neurons within the hidden layer provides higher results. The results for expected output and also the output obtained once coaching square measure compared as shown in table (III). The results for expected output and also the output obtained once coaching square measure compared with the assistance of bar chart for higher understanding as shown in Fig. 12.

Table: III Comparison of Output of standard Relay Output with ANN output

Expected Output of ANN Network	Conventional Relay Output	Output of ANN Based Relay
0	1	0.0566915
0	1	0.0467832
0	1	0.0477842
1	1	0.99997
1	1	0.95266
1	1	0.99999
1	1	0.99996

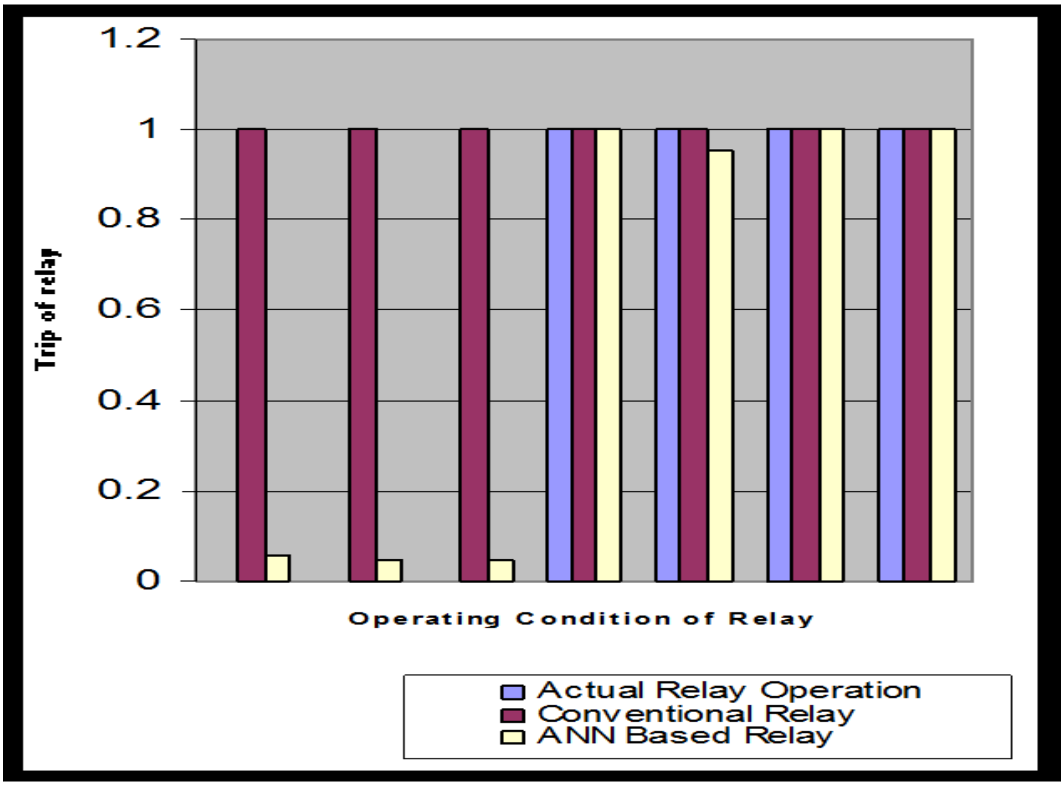

Fig. 12: Bar chart showing Comparison of Output of standard Relay Output with ANN output

VI. CONCLUSION

The introduction of TCSC have improvement in stability; increased active power transfer capability however it creates sure issues to traditional distance protection theme once utilized by transmission lines as there's a modification within the apparent ohmic resistance measured by the relay. The results obtained from simulation {for totally different |for various} sorts of faults and different in operation points (with firing angles α = 60° to 70°) of TCSC. They indicate that presences of TCSC once in operation in electrical phenomenon mode have modified the ohmic resistance measured by the relays utilized by the protection system, that caused mal operations (like over reach) of protecting relay. This mal operation is avoided by ANN trained by Back Propagation rule. ANN primarily based relay provides promising results (for tripping condition (0, 1)) compared to traditional relay with the presences of TCSC. The fault distance may also be obtained with the on top of network by choosing correct coaching pairs which can be bestowed in future work.

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BIOGRAPHY

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