TRANSIENT STABILITY ENHANCEMENT OF TNEB 400 kV TRANSMISSION NETWORK WITH SVC

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***Abstract*— Modeling of the TNEB 400 kV transmission network with SVC using ETAP simulation software is presented in this paper. The system is analyzed under severe disturbance to study the transient behavior by simulating three phase to ground fault at various buses. To enhance the transient stability of the system, SVC are inserted and tested to show the effect of the same on the transient stability under severe disturbances. The study compares the results and effectiveness of SVC for enhancing the transient stability of the system through the critical clearing time using ETAP software. The fault clearing time is increased up to the critical clearing time to test the robustness of the system and the effectiveness of the SVC. Simulation is performed to study the transient behavior of the system. Results show that coordinated modification of exciters, installation of FACTS devices to enhances the stability of the grid to great extent.**

Keywords — Exciter, FACTS, TNEB 400 kV transmission network, Transient stability.

I. INTRODUCTION

Enhancement of transient stability during major faults or outage of equipment is prime concern in widely interconnected power systems in countries like India. Issue is more emphasis after two consecutive block outs in the last year which made one tenth of the world population in dark for two days [30]. This paper deals complete simulation model of 400 kV Tamil Nadu network with an installed capacity of more than 17,000 MW with a peak demand of 12,500 MW. Model of steam, gas and hydro turbine generators which are directly evacuated at 400 kV is considered for simulation**.** Modern power systems are very widely interconnected, because of its operating economy and reliability through mutual assistance. However this large scale interconnection over vide area results in angular and voltage stability problems. Traditionally angular stability was the only constraint however voltage stability also becomes more vulnerable due to modernization and over loading of transmission lines. Set of non linear differential equation and set of algebraic equation represents the mathematical model for a power system to simulate transient stability. Numerical techniques are needed to solve this non linear and algebraic equation [25]. Only steady state analysis {Load Flow and Short Circuit} are preformed to verify the steady state behavior during grid planning and generation transmission expansion. Transient stability is not considered in the planning stage to study the dynamic behavior of the power system due to non availability of simulation model, insufficient input data, non availability of robust software etc., Major block outs on July 30 and 31st 2012 in northern grid of india change the conventional mindsets and emphasis transient stability as a part of grid planning [30].

ETAP (Electrical Transient Analysis Program) is the most effective power system simulation software to perform transient analysis. This paper explains the complete simulation model of 400 kV Tamil Nadu transmission network with an Installed capacity of more than 17,000 MW meeting a peak demand of 12500 MW. This paper is sub divided into three major parts. First part is to identify the critical clearing time of all 400 kV substation in Tamilnadu transmission network without modeling exciter, governor and PSS in the generator. Second part is modeling of AVR, governor, power system stabilizer of synchronous generators, transformers, transmission lines and loads and also find the critical clearing time. Third part discusses the simulation with the results and concludes the paper with proposals to enhance the transient stability of 400 kV substation in the Tamilnadu transmission network.

II. CRITICAL CLEARING TIME

Critical clearing time is the principal criterion for the assessment of transient stability. Fault should be cleared well within the critical clearing time to maintain the transient stability of the power system. Critical clearing time is not sufficient criterion to evaluate the transient stability when considering various scenarios of severe fault occurrence in the power system. The oscillation of generators is basically measured with respect to infinite bus / grid which are

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represented as slack bus. The oscillation level of the generator depends on the disturbance severity and its time duration. If the generator oscillation goes beyond 180 degrees, the generator loses its synchronism and will not be able to regain the steady state. That is, the generator will not be synchronous with rest of the system. Hence, 180 degrees is standardized as the transient stability limit.

A. Modeling of SVC

SVCs, with an auxiliary injection of a suitable signal, can considerably improve the dynamic stability performance of a power system [1]& [2] presented a fundamental analysis of the application of SVC for enhancing the power system stability. Also, the enhancement of low frequency oscillation damping via SVC has been analyzed (3). The SVC enhances the system damping of local as well as inter-area oscillation modes.

Reference [4] studied the nonlinear model interaction in stressed power systems with multiple SVC voltage support. It is observed that SVC controller can significantly influence nonlinear system behavior especially under high-stress operating conditions and increased SVC gains [6]**.**

SVC model shown in Figure 2.1 used to improve the transient stability of the TNEB 400 kV transmission network considered, has been modeled in ETAP. SVC is modeled using ETAP Software.

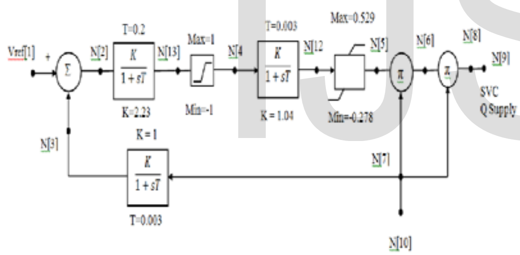

Fig 2.1.Modeling of SVC

B. TNEB 400 k V Transmission network

Tamil Nadu 400 kV transmission network and nearby interconnected substations are considered for the purpose of identifying the critical clearing time at all 400 kV buses to ensure rapid fault clearance and thereby maintaining the transient stability. The system model includes the representation of thirty four 400 kV buses, eleven generators, eleven generators step up transformers etc. Transmission network (only 400 kV) of TNEB is modeled using ETAP. Transmission line parameters of various conductors (Moose and Zeebra) are used as per manufacturer’s standard. Line length and type of conductor are considered as per information available in the Power Grid and Ministry of Power website.

The generators directly connected to TNEB 400 kV transmission network are modeled along with the generator step up transformers. The generator, automatic voltage regulator, turbine governor and transformer data are given in the tables 2.1, 2.2, 2.3 and 2.4 respectively.

The block diagrams of type1 AVR and turbine governor are depicted in Figures 2.2 and 2.3 respectively and fig 2.3 describes the TNEB 400 k V transmission network respectively.

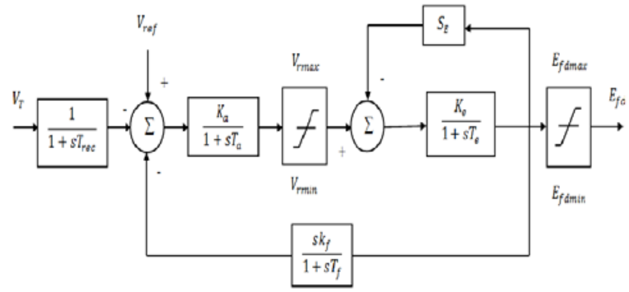

Fig. 2.2 Block diagram of type 1 AVR

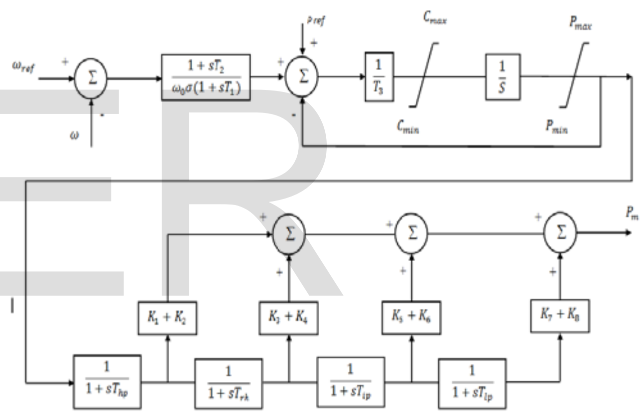

Figure 2.3 Block diagram of turbine governor

Table 2.1 Generator data in TNEB 400 kV transmission network

Generator name	**Rated MVA**	**Rated Voltage (kV)**	**P Schedule MW**	**Qmin**	**Qmax**
Neyveli-1	247	11	163	0	130.03
Neyveli-Ext	295	11	225	0	156.60
Kudamkulam	1111.11	21	850	0	484.32

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Generator name	Rated MVA	Rated Voltage (kV)	P Schedule MW	Qmin	Qmax
Tuticorin-ST4	555.56	21	450	0	242.17
Tuticorin	555.56	21	450	0	242.17
Ind-Bharath	666.67	21	600	0	290.60
Coastal Ene	666.67	21	510	0	290.60
Mettur	555.56	21	450	0	242.17
Chennai JV	733.33	21	637.5	0	319.64
North Chennai	666.67	21	510	0	290.60
North Chennai ABAN	666.67	21	510	0	290.60

Table 2.3 Turbine governor data in TNEB 400 kV transmission network

Variable	Description	Data
σ	Droop	0.04
P_{max}	Maximum power limit	1.1
P_{min}	Minimum power limit	0
C_{max}	Rate of valve opening	0.1
C_{min}	Rate of valve closing	- 1
$K_1 + K_2$	Power extraction at HP turbine	0.276
$K_3 + K_4$	Power extraction at IP turbine	0.324
$K_5 + K_6$	Power extraction at LP turbine	0.4
T_1	Phase compensation 1	0.1
T_2	Phase compensation 2	0.03
T_3	Servo time Constant	0.4
T_{hp}	HP section Time constant in s	0.26
T_{rh}	Reheat section Time constant in s	10
T_{lp}	LP section Time constant in s	999
T_{ip}	IP section Time constant (including re-heater) in s	0.5

Table 2.4 Transformer data in TNEB 400 kV transmission network

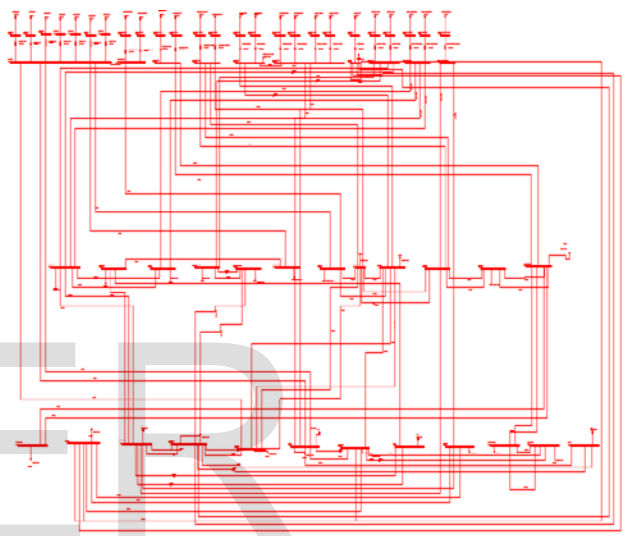

Fig.2.4. 400 kV Tamilnadu grid.

III. SIMULATION RESULTS

A salient feature of the paper is identification of CCT with the help of ETAP which shows the stability of the system from the relative angle {Swing curve} graph and Relation between Critical clearing time and the devices {AVR. Governor, SVC}.

Since a severe fault (three phase fault) is assumed, the ability of the generator to remain in synchronism depends on the fault clearing time. The time to clear the fault is slowly increased up to the critical clearing time with the help of SVC The effect of SVC on the transient stability of the power system is analyzed by creating three phase to ground fault at various buses using ETAP through the critical clearing time. By placing the SVC at various buses independently, the fault clearing time is increased up to the critical clearing time. Critical clearing time for the various buses with SVC at the 400 kV substations, are tabulated in annexture-I and compared

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with critical clearing time without SVC. The ETAP software was then used to simulate the 400 kV TNEB Grid yield validated results.

To simulate the 400 kV Tamilnadu grid ,models have been developed for each element and implemented in the dedicated power system simulation tool ETAP which provides the ability to simulate load flow study, short circuit study and Transient events in the same software environment. The ETAP simulation tool therefore has a dedicated model for induction generators which take into account the current displacement in the rotor, the torque slip and short circuit test curves. Also models of synchronous machines, transformers, bus bars, grid models, Transmission lines etc are provided.

The swing curves of generators for a three phase fault at different substation with different scenario is presented here.Fig shows the simulation result for 400kV bus outage and the fault occur at 3 sec and also find the system performance with the presence of exciter, governor, and PSS and without those.

The swing curve of the generators inclusion of Exciter, Governor, and PSS the critical clearing time is increased by 206 ms is represented in the Fig 9. This will be certainly helpful to maintain the stability, when the backup protection isolates the fault due to primary relay failure.

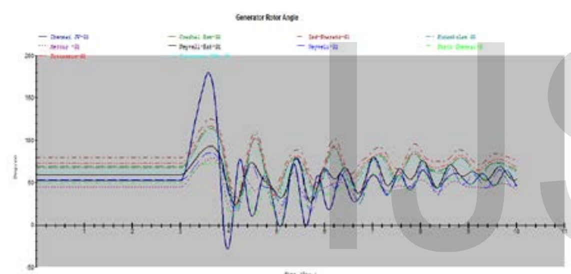

Fig.9. Swing curves of generators with inclusion of exciter,governor,PSS.

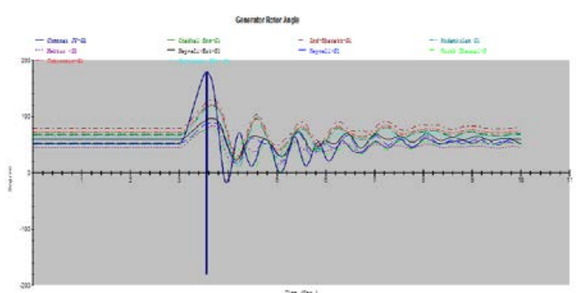

Fig 10.Swing curves of generators with inclusion of exciter and PSS.

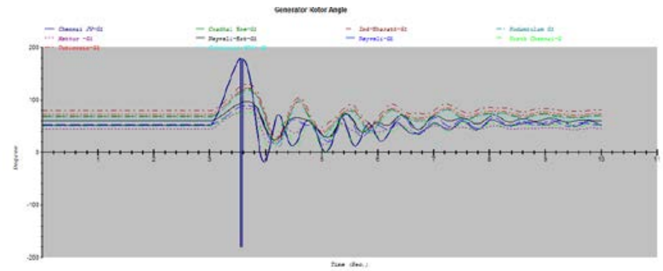

Fig 11.Swing curves of generators with inclusion of static exciter

Changing the droop constant from 5% to 4% the critical clearing time of the 400 k V tamilnadu grid is increased by 168 ms. If the fault clearing time exceeds the 168 ms the oscillation of the generators exceeds 180 degree is shown in the Fig 12.

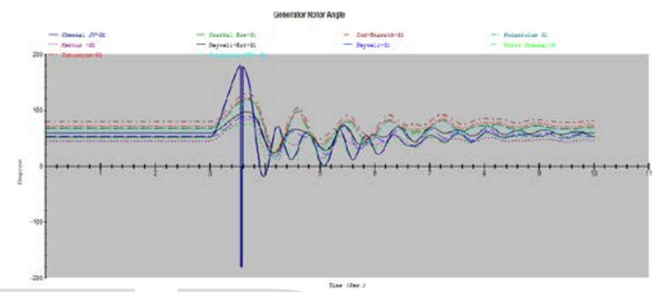

Fig 12. Swing curves of the generators for changing the droop constant

The swing curves of generators in Neyveli, Neyveli Ext, Tuticorin, North Chennai, Mettur for Bus outage fault at Alamanthi 400 k V substation without Exciter, Governor and PSS are shown in Fig 13.The critical clearing time of this case is 166 ms. If fault clearing time exceeds 166 ms , the oscillations of generators exceeds 180 degrees shown below.

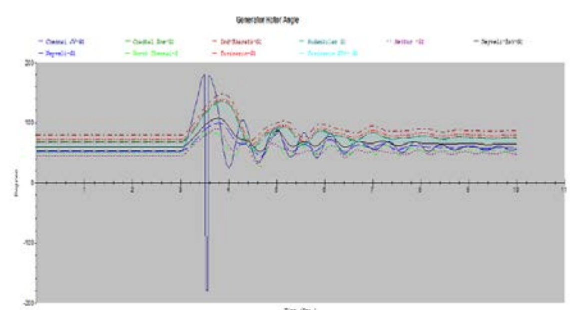

Fig 13.Swing curve of generators without using Exciter,Governor,PSS.

The swing curves of generators in Neyveli, Neyveli Ext, Tuticorin, North Chennai, Mettur for Bus outage fault at Alamanthi 400 k V substation without Exciter and Governor are shown in Fig 14.The critical clearing time of this case is 171 ms. If fault clearing time exceeds 171 ms , the oscillations of generators exceeds 180 degrees shown

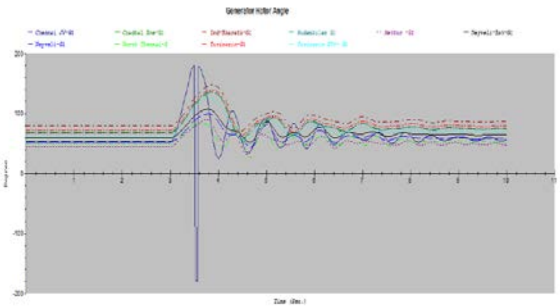

Fig 14.Swing curve of generators with Exciter and Governor.

In the system with dc excitation the fault cleared is not within the time, but if we used the static system the CCT Is increased. An occurrence of three phase fault on the bus and clearance of the fault within a short period of time (upto 100 ms) does not represent a large risk to the power system in terms of transient stability. For this reason, it is necessary to ensure that generators operating in the electric power system have a critical clearing time higher than 100 ms. The comparison of the CCT is listed in the table 1 in annexure.

The critical clearing time of the 400 kV tamilnadu grid is improved while using SVC. Impact of SVC on the transient stability is analyzed with the help of critical clearing time. Critical clearing time at Madurai 400 kV substation without SVC is 136 ms. Considering the relay delay time(40 ms)and circuit breaker opening time (30 ms)in the Madurai substation, the relay and circuit breaker fails to isolate the fault during N-1contingency(i.e during struck breaker operation-after struck breaker, all other breaker should open to isolate the fault)within the critical clearing time. However ,with SVC installation at various buses, the critical clearing time is increased from 136 ms to around 179 ms. This increased cushion of 43ms(>1.5 cycle)will maintain the stability for three phase fault at Madurai even N-1 contingency.

V.*DISCUSSION AND CONCLUSION*

In this paper simulation of 400 kV Tamilnadu transmission network has been presented .A 400 kV Tamilnadu transmission network model has been built to simulate the influence on the transient stability of power system with the presence of SVC. The critical clearing time of the system for various contingencies was found and tabulated. From that result the average critical clearing time of the system is high when the SVC is present. Hydro generators are not directly evacuated to 400 kV transmission network, hence the hydro turbines are not modeled in this paper and also the bus outage contingency is only taken in to account. In future the system performance can be analyzed with auto reclosure.

VI.REFERENCES

[1] Byerly, R. T. D., Poznaniak, T. and Taylor, E. R. “Static Reactive Compensation for Power Transmission System”, IEEE Transaction. PAS-101, pp. 3998–4005, 1982

[2] Hammad, A. E. “Analysis of Power System Stability Enhancement by Static VAR Compensators”, IEEE Trans.PWRS, Vol. 1, No. 4, pp. 222–227, 1986.

[3] Padiyar, K.R. and Varma, R.K. “Damping Torque Analysis of Static VAR System Controllers”, IEEE Transactions on Power Systems, Vol. 6, No. 2. pp. 458-465, 1991.

[4] Messina, A. R. and Barocio, E. “Nonlinear Analysis of Interarea Oscillations: Effect of SVC Voltage Support”, Electric Power Systems Research, Vol. 64, No. 1, pp. 17–26, 2003.

[5] Abido,M. A. “ Analysis and Assessment of STATCOM –Based Damping Stabilizers for Power System Stability Enhancement”, Electric Power System Research,Vol.73,No.2,pp.177-185,2005.

[6] Abido,M. A. “Power System stability Enhancement using FACTS Controllers:A Review “,The Arabian Journal for Science and Engineering,Vol.34,No.2B,pp.153-172,2009.

[7] Al-Baiyat,S. A. “Power system Transient Stability Enhancement by STATCOM With Non-linear H α Stabilizer”,Electric Power Syatems Research,Vol.73,No.1,pp.45-52,2005.

[8] Anderson,G. “Dynamics and Control of Electric Power Systems”,Zurich,Switzerland:EEH-Power Systems Laboratory ETH,2004.

[9] Begovic,M.”Defense Plan Against Extreme Contingencies,CIGRETF-Summary for Electra”, C2.02.24,2007.

[10] Van Custem,T.and Vournas,C.”Voltage Stability of Electri Power Systems”, Norwell,MA:Kluwer,1998.

[11] Sauer,P.W.and Pai,M. A.” Power System Dynamics and Stability”,Prentice Hall,1998.

[12] Taylor,C.W.”Power System Voltage Stability”, MC Graw Hill,New York,1994.

[13] Van Custem,T. and Mailhot ,R.”Validation of fast voltage stability analysis method on the Hydro Quebee System”, IEEE Transaction Power System,Vol.12,pp.282-292,1997.

[14] Van Custem,T. and Mailhot ,R. Validation of fast voltage stability analysis methods “, Proc.IEEE ,Vol.88,pp.208-227,2000.

[15] P.Kundur and P.C.Dandeno,”Implementation of synchronous machine models into power system stability programs,”IEEE Trans,Vol.PAS-102,pp 2047-2054,July 1983.

[16] IEEE Committee Report,”Proposed Excitation system Definitions for synchronous machine,”IEEE Trans Vol.PAS-88,pp 1248-1258,August 1969.

[17] IEEE Committee Report,”Excitation system models for power system stability studies,”IEEE Trans ,Vol.PAS-100,pp 494-509,February 1981.

[18] W.A.Lewis,”A Basic Analysis of Synchronous machines-Part-I, AIEE Trans,Vol.77 , pp. 436-456, 1958.

[19] I,M,Canay,” Extended Synchronous Machine model for the calculation of Transient Processes and stability ,”Electrical Machines & Electro mechanics, Vol-I,pp.137-150,1977.

ISSN 2229-5518
[20] C.Concordia and S.Ihara," Load representation in Power System Stability Studies," IEEE Trans,Vol.PAS,101,pp.969-977,April-1982.

[21] D.S.Brereton,D.G.Lewis and C.C.Young," Representation of Induction motor Load during Power System Stability Studies,AIEEE Trans,Vol-76,Part-III,pp 451-460,August.1957.

[22] EPRI Report of Project RP 849-1,"Determining Load Characterristics for Transient Performance," EPRI EL-850,Prepared by General Electric Company, March.1981.

[23] P.Kundur,M.Elein, G.J.Rogers, and M.S.Zywno," Application of Power System Stabilizers for Enhancement of overall System Stability,"IEEE Trans, Vol.PWRS-4,No-2, pp.614-626, May 1989.

[24] Zhou,E.Z."Application of Static Var Compensators to Increase Power System damping",IEEE Transactions on Power Systems,Vol.8,No.2,pp .655-661,1993.

[25] Yong Hua Song and Allan Johns,T."Flexible AC Transmission Systems(FACTS)",London,UK:IEE Press,1999.

[26] www.cea.nic.in\reports\planning\power_scenario.pdf.

[27] Wang,Y.,Mohler,R.,Spee,R.andMittelstadt,W."Variable Structure FACTS Controllers for Power System Transient Stability", IEEE Trans,PWRS,Vol.7,pp307-313,1992.

[28] Van Custem,T.and Vournas,C."Voltage Stability of Electric Power Systems", Norwell,MA:Kluwer,1998.

[29] P.Kundur,"Power System Stability and Control'',McGraw-Hill,Inc.

[30]http://spectrum.ieee.org/energywise/energy/the-smarter-grid/a-postmortem-on-indias-blackout

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ANNEXURE- I

Critical Clearing Time of 400 kV TNEB transmission network for various contingencies using ETAP							
ID	WO exciter,governor,pss,SVC	with exciter,governor,pss	with exciter, governor	with exciter & pss	with exciter static	with governor droop change(4)	Using SVC
Alamanthi	166	206	171	169	169	168	234
Arasur	224	343	279	260	260	245	281
Melakuttaiyur	298	321	322	315	314	305	356
Sholinganallur	399	514	499	474	474	420	636
Pondicherry	378	577	581	499	499	426	699
Trichy	207	260	261	246	246	225	277
Karaikudi	141	167	167	161	161	151	188
Madurai	136	163	164	157	157	146	179
Kayathar	136	157	157	153	152	145	186
TM-Wind	139	161	160	155	155	147	194
Thirunelveli	129	147	147	144	143	137	168
SVC-4	224	236	236	232	232	229	259
Singarpet	173	207	208	197	197	187	238
Pugalur	158	192	192	183	183	170	246
Udumalpet	168	203	203	183	192	182	239
Karamadai	324	444	447	396	396	365	469
Muvattupuzha	216	262	262	248	248	234	284
N_Thichur	219	269	270	252	252	238	297
Trivandrum	342	465	467	433	432	381	488
Average	**240.3**	**278.6315789**	**273.3157895**	**255.6315789**	**255.8947368**	**268.85**	**311.47**