Optimal Location of Phase Shifting Transformer for Load alleviation

PROJECT THESIS

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By

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THESIS CERTIFICATE

This is to certify that the project work entitled **OPTIMAL LOCATION OF PHASE SHIFTING TRANSFORMER FOR LOAD ALLEVIATION** submitted by **Vibin M,** EE14B110, to **Indian Institute of Technology Madras** in partial fulfillment of the requirements for the award of degree of **Master of Technology**, is a bonafide record of work carried out by him. The contents of this report, in full or part have not been submitted to any other Institute or University for the award of any degree or diploma.

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ABSTRACT

KEYWORDS: Power Transmission, Renewable Energy Integration, Phase Shifting Transformers (PST), Combinational Algorithm

Analysis and enhancement of Tanjore power grid by implementing an algorithm for optimal load alleviation. The optimal location and placement of Phase Shifting Transformers for effective load alleviation over a particular transmission network in Tamil Nadu is discussed in this project.

DigSilent Power Factory software is used to simulate various scenarios. The crucial system parameters with and without PST is discussed elaboratively. The results are formulated in Microsoft Excel and calculations are made. A combinational algorithm is devised to identify the best location for placing the PST. Different parameters for effective functioning of the grid and determining the optimal location by these parameters are discussed. The results convey that the line TVARUR-TANJORE is the optimal location for placing the PST.

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ABBREVIATIONS

UPFC	Unified Power Flow Controller
IPFC	Interline Power Flow Controller
PST	Phase Shifting Transformer

NOTATION

P_{is}	Real Power injected through i bus, MW
Q_{is}	Reactive Power injected through i bus , MVar
P_{js}	Real Power injected through j bus, MW
Q_{js}	Reactive Power injected through j bus, MVar
γ	Angle Injected by PST, ^{o}
θ_j	Angle between bus i and j, ^{0}
V_i	Sending End Voltage, V
V_j	Receiving End Voltage, V
V_s	Voltage injected by PST, V
σ	Line Power Standard Deviation from normal values
μ	70 percent line Nominal Power(pu)
ω_i	Weighting Factor of line
N	Number of lines
p_i	Power of each line(pu)
P_{loss}	Loss experienced in Grid under Simulation, MW

CHAPTER 1: INTRODUCTION

1.1 OPTIMAL LOADING OF TRANSMISSION LINES USING PHASE SHIFTING TRANSFORMERS (PST)

Transmission lines are the back bones of a power grid. Utilizing transmission lines effectively, at the highest capacity is very crucial. Preventing further construction of more lines is crucial as it reduces the expenditure and time invested in construction. This can be done by reducing the load in overloaded lines. In India, different parts of the country have varied loading conditions and varied connection topology for transmission lines. Because of this the lines are not optimally loaded. Some lines are overload and some lines are underload which results in power outages and voltage fluctuations. In order to tackle this problem, a variety of equipment can be used. One of them is a Phase Shifting Transformer (PST). PST is an attractive solution for this problem as it is relatively less costly than other equipment like IPFC, UPFC etc.

1.2 NEED FOR PRESENT STUDY

In Tamil Nadu, certain transmission lines are heavily loaded because of their connections to various major industrial cities and towns. In some cases, varied loading situations occur at various places. Rapid expansion of the power grid network also means that newer lines need to be constructed to counter the hugely increasing loads. This means that the government has to spend lots of money and invest a lot of time. This also causes parts of the grid to be shutdown for expansion. Newer transmission towers, underground canals need to be constructed. So, a minimally invasive solution should be thought of. Phase Shifting Transformers prove to be an attractive option as the cost benefit is good and also it reduces the time consumed in the grid expansion.

1.3 OBJECTIVES AND SCOPE OF RESEARCH

This thesis tlks about the usage of Phase Shifting Transformer in Tamil Nadu grid context for effective loading of transmission lines. This leads us into the subsequent objectives.

1. Relating the system indices with, and without PST

In order to install the Phase Shifting Transformer, we shall devise a Combinational Algorithm The optimal location of the Phase Shifting Transformer will be achieved by using the combinational algorithm.

The parameters are namely, Voltage Profile of the line, Line Loading and System Losses. Thus, these three parameters are represented in the combinational algorithm using various indices that are present in the algorithm. Also, the observation of the variation of the system indices with and without the presence of PSTs is also discussed.

2. Finding the optimal location of PST

In a complex power grid, like the Tamil Nadu power grid, various transmission lines are present where Phase Shifting transformers can be installed to lessen a range of difficulties like overvoltage, line overloading. Since numerous lines are present, it translates to numerous combinations for installing the PST. In a perfect situation, we would like to regulate the power flow by using a regulatory device in all the lines so that optimal control of the grid can be attained. But it is not economically viable to install a PST at each line. Thus, we have to determine the optimal location using different algorithms.

3. Analysis of Voltage Profile of the line, Line Loading and System Losses with PST

We have to assess and analyze the power grid by comparing the three different parameters of the system that correspond to the overloading of the grid, the Voltage profile and System losses in the combinational algorithm.

1.4 ORGANIZATION OF THESIS

This thesis is organized into 3 chapters.

Chapter 2 explains the modelling of Phase Shifting Transformer both theoretically and with the help of PowerFactory software. It also discusses how a normal 3 phase transformer can be altered into a Phase Shifting Transformer by changing certain working modes. The usage of having a Phase Shifting Transformer in a transmission line is also explained. After that, a standard nine bus system is analyzed in PowerFactory with and without the presence of PSTs. The loadings of the line are observed and inferences are drawn.

Chapter 3 explains the various components and usage of Combinational Algorithm to find the optimal PST location in a power grid in order to mitigate various grid problems like overloading, system losses, and over-voltages. It discusses the modelling of the Tanjore Grid in Tamil Nadu in PowerFactory, its base case simulation without PST, its loading conditions are obtained. Then, a PST is inserted in all the lines of the Tanjore Grid individually, and the loading conditions and system parameters are calculated and represented graphically for better understanding. Finally, the optimal location for PST placement is determined by considering the three parameters.

Chapter 4 concludes the thesis and then discusses the future scope of the work.

CHAPTER 2: THEORY, MODELING, AND BASIC OPERATION

2.1 INTRODUCTION

In this chapter, we discuss how the active and reactive power in a particular line is affected by inserting a Phase Shifting Transformer. Also, the principle behind the working of a PST is also discussed. Apart from that, different types of phase shifting transformers are also discussed, briefly.

The different cases are simulated in Power Factory Software. We also discuss how the modeling of a Phase Shifting transformer is done by changing the parameters of a normal transformer. Finally, we demonstrate the usage of Phase Shifting Transformer in a standard 9 bus model to mitigate the various problems like overloading.

2.2 POWER FLOW CONTROL

In the past, operating a power grid was relatively straightforward. The grid was designed to supply electricity to the region in which it was built and to support the neighboring regions. However, it has changed now. Transmission grids now are used to transport power not necessarily in the local region. Lately, high voltage transmission systems have become more and more loaded by electrical power systems. This reduces the security of power systems. Losing stability in a transmission system in a high voltage system poses serious problems. This also leads to overloading of multiple lines at the same time which makes the system very vulnerable and causes reliability and security issues in the network.

Overloading of lines is usually caused by transmission line outages, generator outages, etc. In any of the above cases, overloading can be eased by redirecting power flow from overloaded lines to less loaded lines. This can be achieved in many ways. Due to increasingly complicated power grids and a rising energy market, the ability to regulate the power flow has become crucial. Therefore, the goal is to achieve real power control and reducing overloading. This can be attained by Phase Shifting Transformers (PST). They are secure, stable and relatively economical than FACTS (Flexible Alternating Current Transmission System) devices, e.g., dynamic-flow controller and unified/interline power-flow controller.

PSTs transfer power flow from an overloaded transmission line of the power system to lines with free transmission capability. The control of active power flow is attained by adjusting the phase angle of the voltages at the phase-shifting transformer terminals. The power flow in a transmission line when PST is connected is as shown [4]

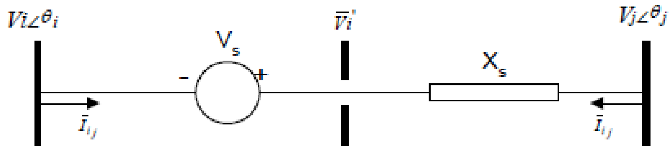


Figure 2.1: Equivalent model of PST in line

Assume a series voltage source between buses *i* and *j* of the transmission system. In Fig. 1, series voltage source is depicted by an ideal source with the voltage and reactance *Xs*.

The power flow is as shown[4]:

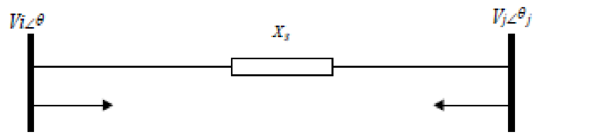
$$P_{is} = rb_s V_i^2 \sin\gamma \quad (2.1)$$

$$Q_{is} = rb_s V_i^2 \cos\gamma \quad (2.2)$$

$$P_{js} = -rb_s V_i V_j \sin(\theta_{ji} + \gamma) \quad (2.3)$$

$$Q_{js} = -rb_s V_i V_j \cos(\theta_{ji} + \gamma) \quad (2.4)$$

Here the power flow is varied when PST varies the value of "γ". PST can vary the value of both "γ" and "r". "r" is factor that affects the value of voltage[4].



$Q_{si} = rb_s V_i V_j \cos\gamma$ $\quad Q_{sj} = -rb_s V_i V_j \cos(\gamma + \theta_{ji})$

$P_{si} = rb_s V^2{}_i \sin\gamma$ $\quad P_{sj} = -rb_s V_i V_j \sin(\gamma + \theta_{ji})$

Figure 2.2 : Power Flow in line with PST insertion

Here

P_{is}= Real Power injected through i bus

Q_{is} = Reactive Power injected through i bus

P_{js}= Real Power injected through j bus

Q_{js} = Reactive Power injected through j bus

γ = Angle Injected by PST

θ_{ji}= Angle between bus i and j

V_i = Sending End Voltage

V_j= Receiving End Voltage

V_s = Voltage injected by PST

PSTs exist in many different forms. They can be classified by the following characteristics [10]

1. **Direct PSTs:** They are based on one three-phase core. The phase shift is obtained by connecting the windings in an appropriate manner to each other.
2. **Indirect PSTs:** They are based on construction using two separate transformers: one variable tap exciter to regulate the amplitude of the quadrature voltage and one series transformer to inject the quadrature voltage in the line.
3. **Asymmetrical PSTs** create an output voltage with an altered phase angle and amplitude compared to the input voltage.
4. **Symmetrical PSTs** create an output voltage with an altered phase angle compared to the input voltage, but with the same amplitude.

In PST taps are present; the physical control of the power is done by varying the tap position of the PST. Corresponding to each tap position an angle is introduced in the line and as per the formulae mentioned above, the power flow varies.

2.3 MODELING OF PHASE SHIFTING TRANSFORMER

In this project, we have used Power Factory software for simulation and modeling the Phase Shifting Transformer. The PST is modeled in Power factory as shown.

We convert a normal transformer into a PST by changing a few settings as shown:

1. Firstly, a normal auto transformer is selected and connected between the two nodes as required. Then we modify the type of the selected transformer.

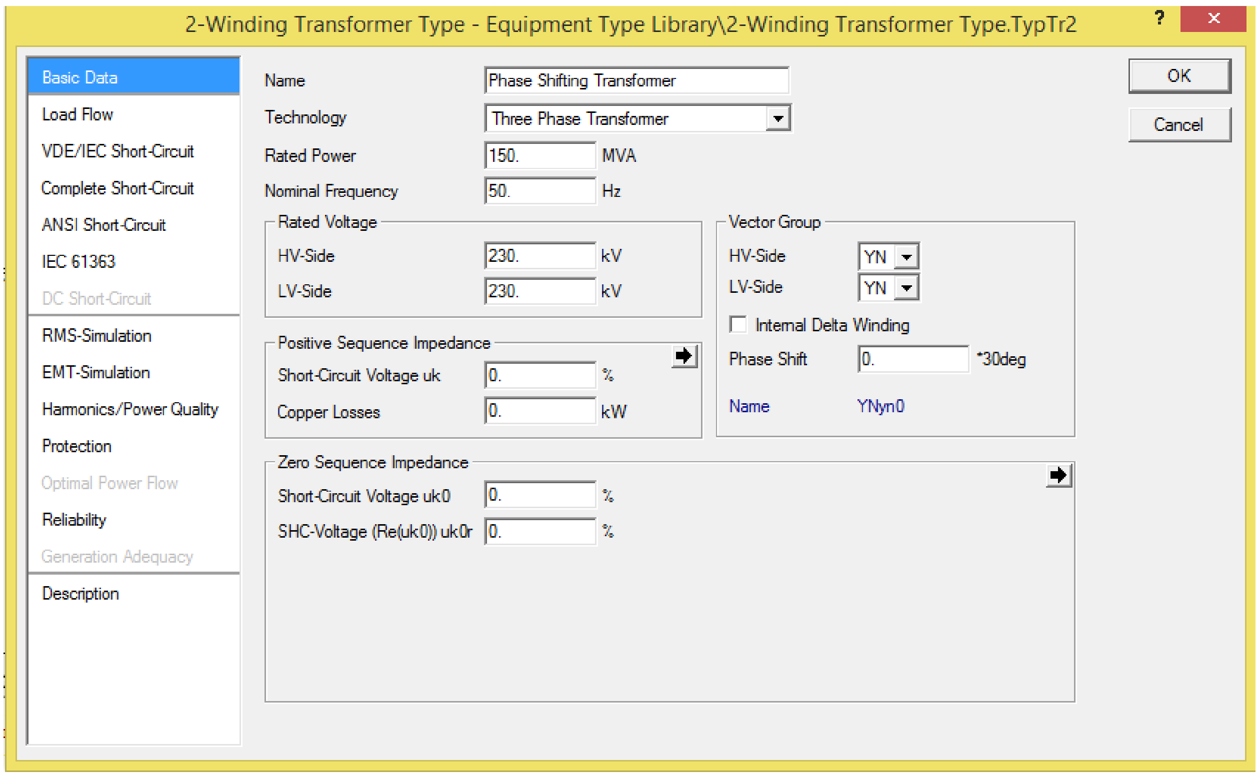


Figure 2.3: Selecting Transformer Type in Power Factory

A transformer of 150 MVA is selected with a nominal frequency of 50 Hz. The HV and LV sides are kept at 230 kV. And we assume zero copper losses.

2. After that, we alter the "Load Flow data", and assign the "Tap Changer" to be ideal as shown below. Here, we have selected the degree/tap as 3. The minimum tap position is set as -20 and maximum tap position as +20. The neutral position is set as 0.

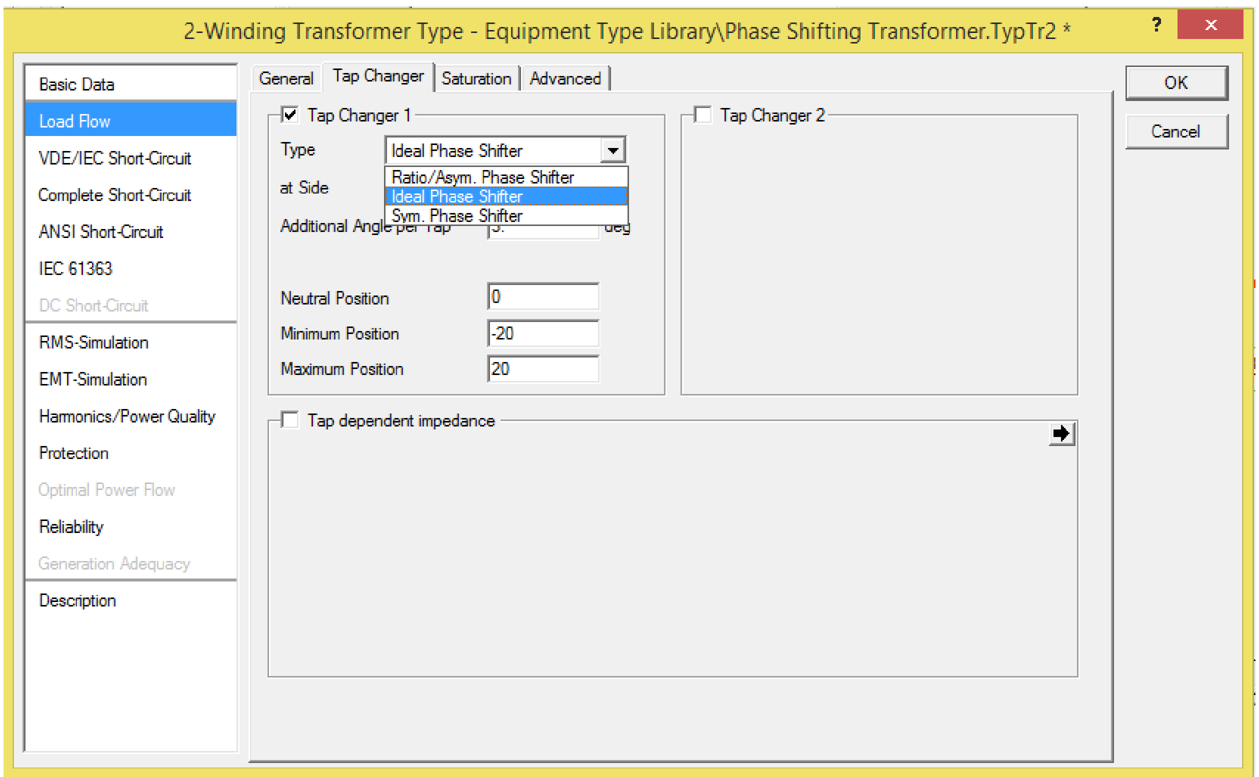


Figure 2.4: Transformer Tap Changer Menu in Power Factory

3. Then, the control mode is changed to P. Here we have selected the Active Power set point i.e. the value which the controller will attempt to keep in the line to be -100 MW, the negative sign denotes the direction of power flow.

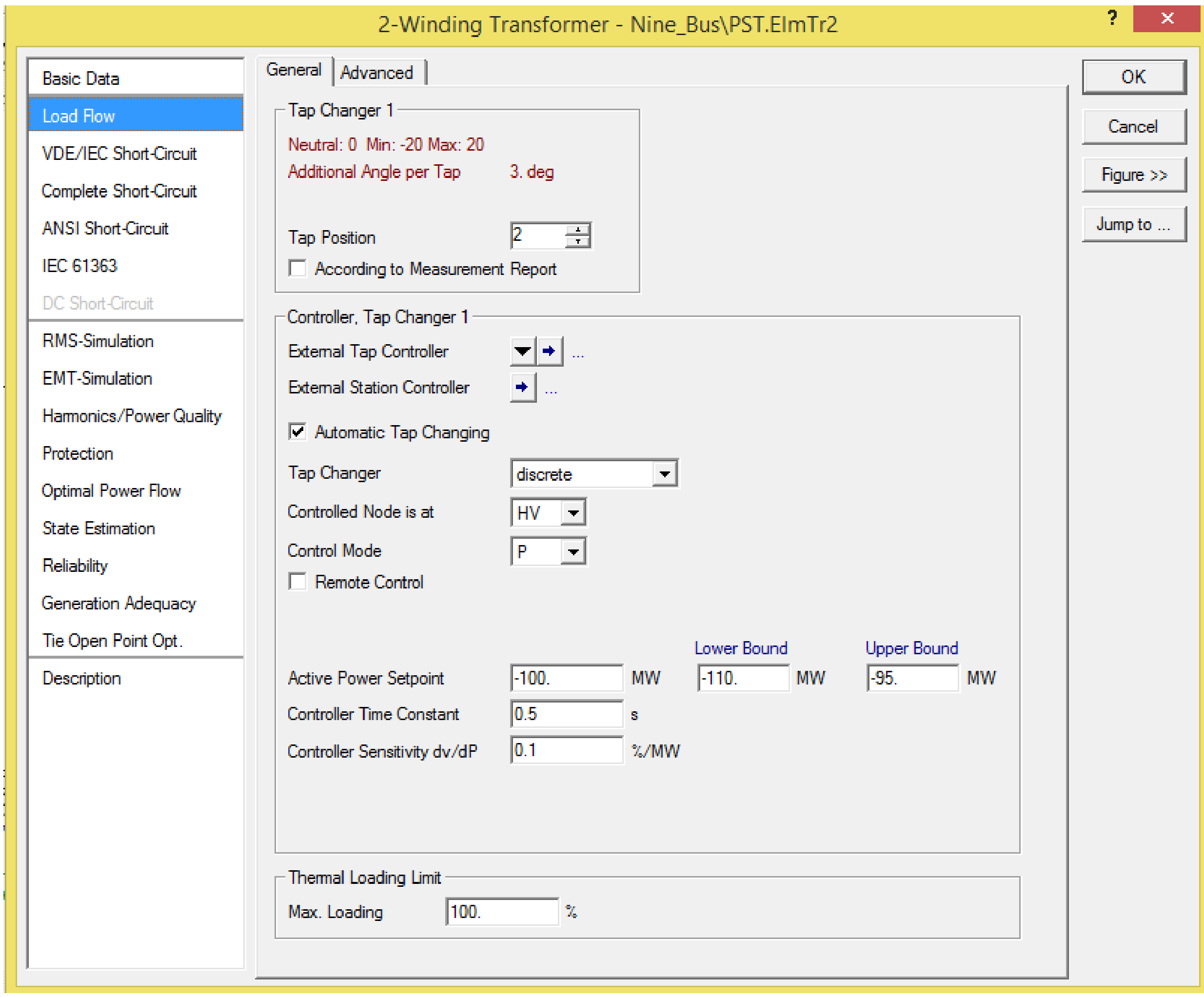


Figure 2.5: Load Flow Control of Transformer in Power Factory

2.4 POWER FLOW CONTROL

2.4.1 BASE CASE SIMULATION (9 BUS SYSTEM)

We check the functionality of a Phase Shifting Transformer in a system by simulating it in a 9-bus system. We consider a standard 9 bus system and keep the values of the elements appropriately to simulate an overloaded line and we finally alleviate the load by using a PST.

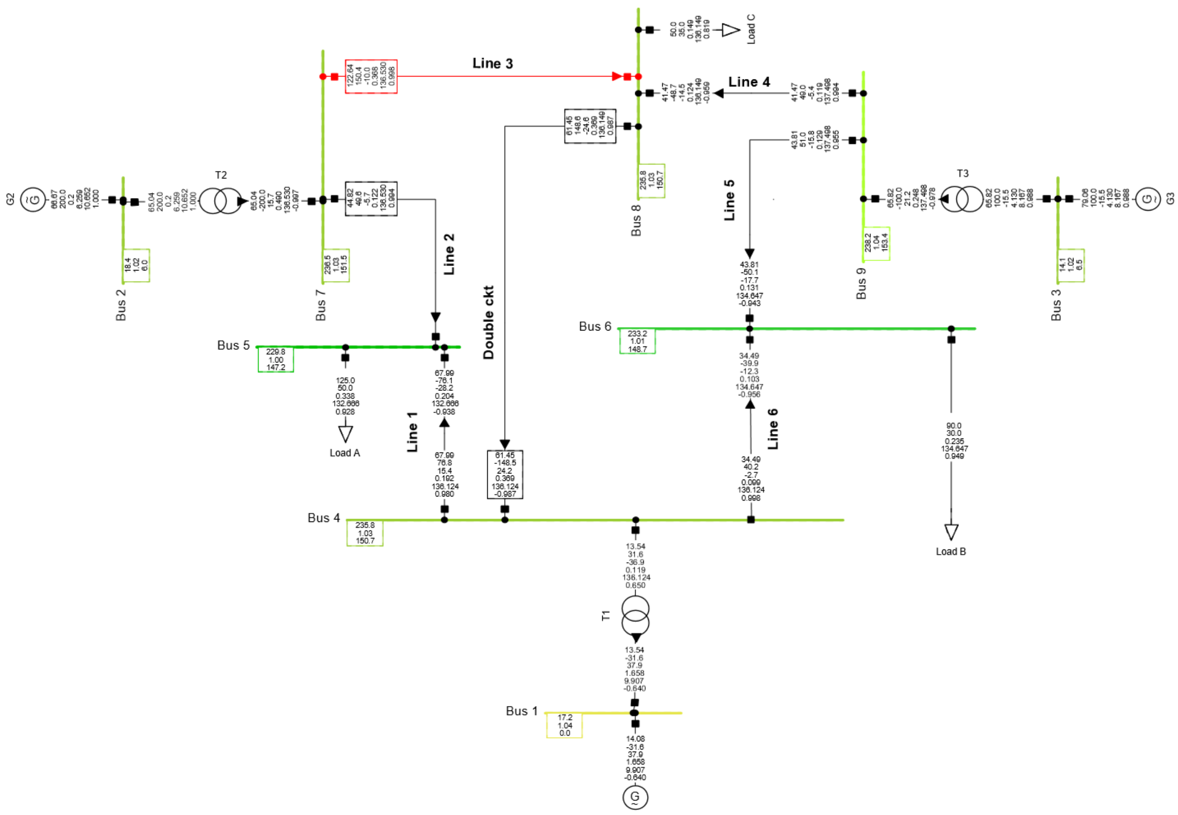


Figure 2.6: Base case simulation of Nine Bus system

The specifications of the above nine bus grid are as shown:

The Generator specifications are shown below:

Table 2.1: Specifications of generators

GENR	MVA	KV	pf	P	Q	V	angle
1	300	9.907	1	0	0	1.04	0
2	200	8.167	0.99	200	0.2	1.025	0
3	100	10.652	0.98	100	0.2	1.025	0

The specifications of lines are shown below:

Table 2.2: Specifications of lines

LINE	LENGTH	I-RATED	R(ohm)/km	X(ohm)/km
1	1	0.3	5.29	44.965
2B	1	0.3	16.928	85.169
3	1	0.25	2.4965	9.088
4	1	0.3	6.2951	53.3232
5	1	0.3	20.631	89.93
6	1	0.3	8.993	48.668
DOUBLE CKT	1.5	ACSR PANTHER		

The Load specifications are as follows:

Table 2.3: Specifications of Loads

LOAD	P	Q	V
A	125	50	1
B	90	30	1
C	250	35	1

The Transformer specifications are as follows:

Table 2.4: Specifications of Transformers

TRANSOFRMER	MVA	HV	LV
T1	350	230	16.5
T2	300	230	18
T3	150	230	13.8

After the simulation, the line loadings are as follows:

Table 2.5: Line loadings in base case simulation of standard Nine bus system

LINE	LOADING
1	67.99
2	44.82
3	122.64
4	41.47
5	43.81
6	37.69
DOUBLE CKT	61.45

We clearly understand that Line 3 is overloaded with an overload of 122.64 percent. We also see that the other lines are not loaded optimally. In order to alleviate this situation, a PST is inserted in the overloaded line. We have modeled the PST as explained in section 2.1. We have selected a 150MVA transformer (ideal) with -20 to +20 taps with 0 as neutral position and degree/tap = 3, the taps are present at the high voltage side.

The simulation with PST is shown below:

We have simulated the grid with two cases.

Case 1: PST on line 3

Case 2: PST on line 2

We then compare the loadings of the transmission lines to get an idea of how the placement of the PST plays a major role in optimal transmission.

CASE 1: PST on line 3

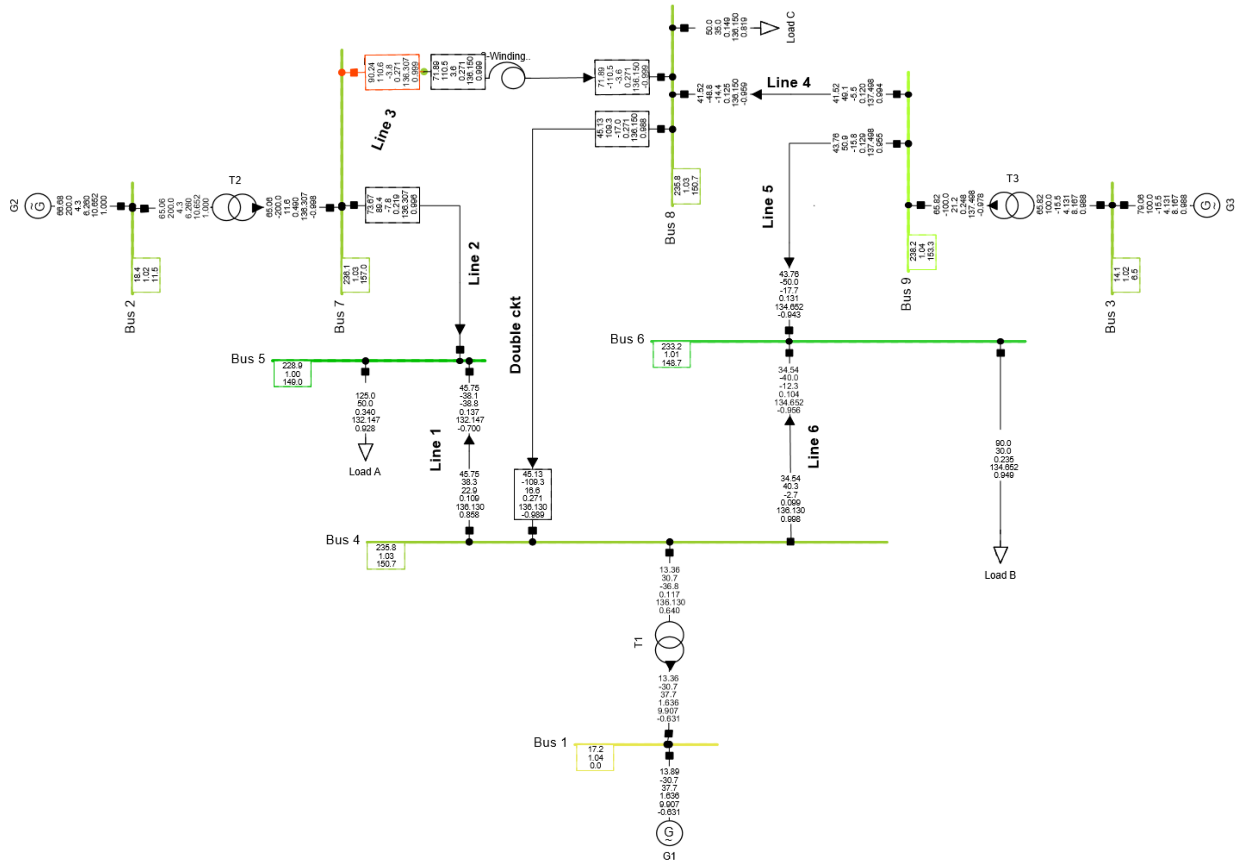


Figure 2.7: Nine bus system after PST installation in line 3

As we see the table below, we can interpret that the loading in Line 3 id reduced from 122.64 percent to 90.24 percent. We also see changes in line loadings on other lines.

Table2.6: Line loadings in the standard Nine bus system with PST on line 3

LINE	LOADING
1	45.75
2	73.67
3	90.24
4	41.52
5	43.76
6	34.54
DOUBLE CKT	45.13

CASE 2: PST on line 2

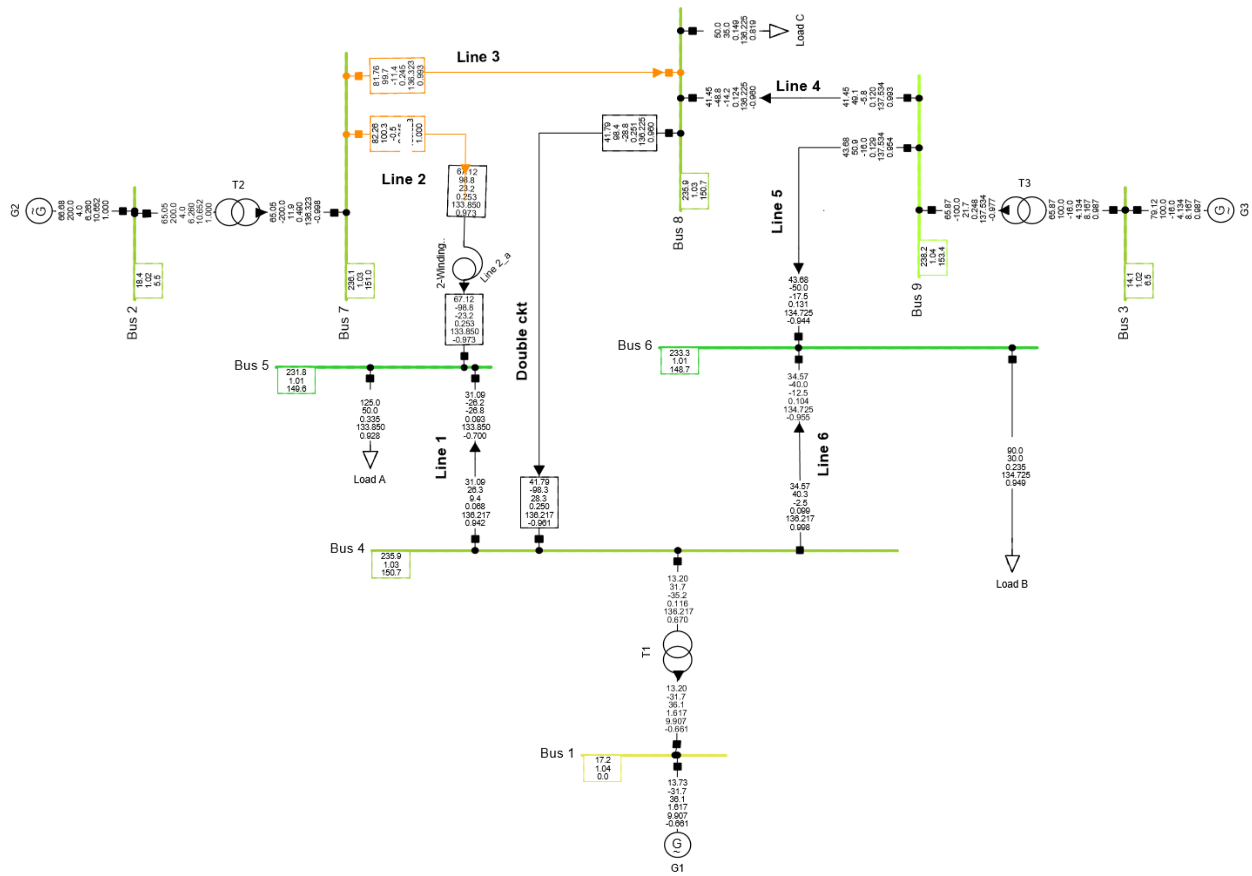


Figure 2.8: Nine bus system after PST installation in Line 2

Installing the PST in Line 2, we find that the loading in line 3 reduces from 122.64 percent to ---percent. Though loading in line 2 has increased from the base case, it is within the limits.

Table2.7: Line loadings in the standard Nine bus system with PST on line 3

LINE	LOADING
1	31.09
2	67.12
3	81.76
4	41.45
5	43.68
6	34.57
DOUBLE CKT	41.79

Therefore, we have 7 options for the placement of PST in this grid. We determine the optimal placement of the PSTs using combinational algorithm.

2.5 SUMMARY

We have discoursed how Phase Shifting Transformer can be modeled in Power Factory using its basic functionalities and by modifying its features a little bit, we were able to model it in the software. Its various mathematical relations pertaining to its effect on the line real and reactive power is also discussed.

we got to know that the overloading that is experienced by the 9 -bus grid above can be alleviated by using the PST. But, the various permutations for the position of PST gives us a challenge to find that best location. Therefore, an algorithm needs to be implemented to determine the optimal location.

CHAPTER 3: OPTIMAL PLACEMENT OF PHASE SHIFTING TRANSFORMER IN TANJORE GRID

3.1 INTRODUCTION

In order to understand the optimal placement of the Phase Shifting Transformer in a grid, we have chosen the Tanjore grid in Tamil Nadu. In order to analyse the system's behaviour, the grid is analysed at peak duration. To mitigate the loading issues, PST (Phase Shifting Transformer) will be used, and optimal location of the PST will be done using Combinational algorithm.

The system indices are varied and the system is analysed with the insertion of PST, the tap positions are varied and the relative change in system parameters are discussed. The explanation of the various parameters on what they mean and how it translates to system performance is discussed. It is followed by the determination of the optimal position for the PST.

The graphical interpretation of these parameters are also shown and how various mathematical tools like standard deviation and coefficient of variance can be used to determine the best PST location is discussed.

3.2 ANALYSIS OF TANJORE GRID

3.2.1 MODELING

The grid is modelled in PowerFactory software and appropriate values of system parameters are inserted properly. All the system values are entered in absolute value. The modelled Tanjore grid in base case is shown below:

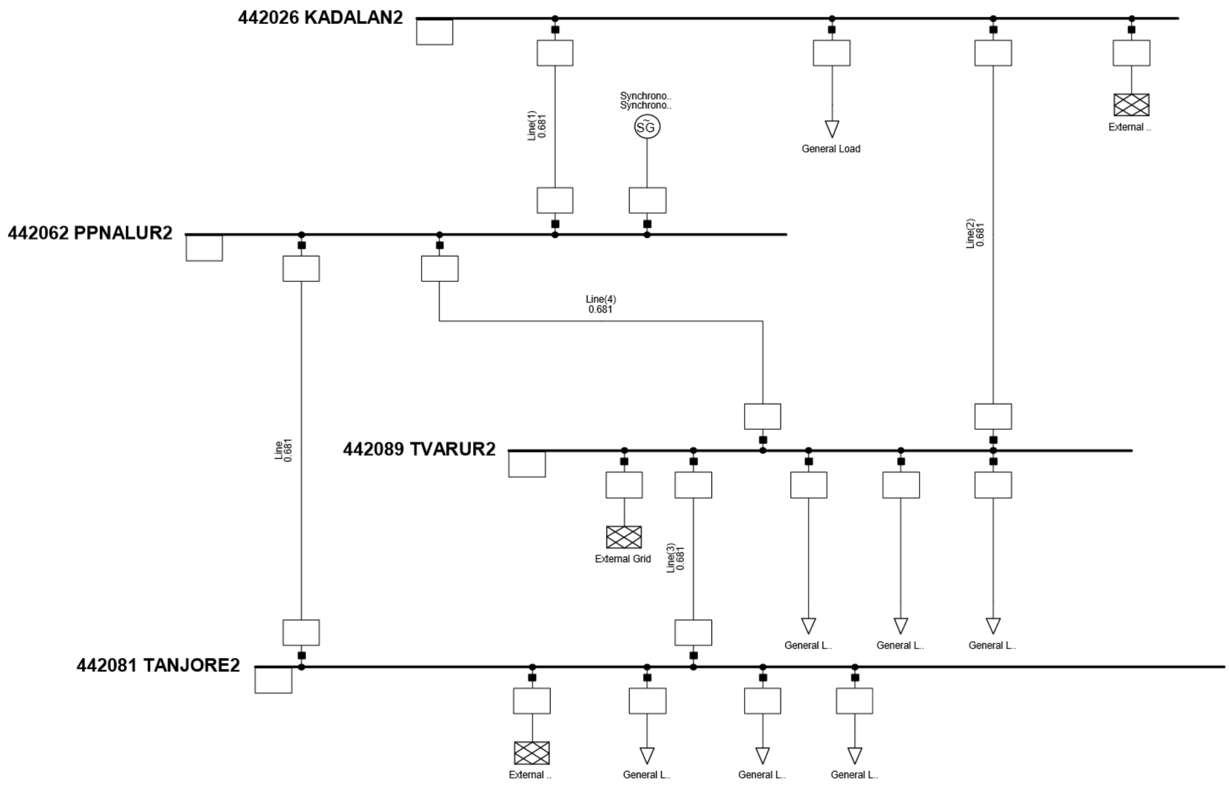


Figure 3.1: Tanjore Grid modelled in PowerFactory

The grid consists of four 220 KV buses with five transmission lines connected between the buses. The line details are as follows:

Table 3.1: Line details of Tanjore Grid

LINE	DISTANCE (km)
KADALAN-PPNALUR	33
KADALAN-TVARUR	55.5
PPNALUR-TANJORE	106
PPNALUR-TVARUR	44.6
TVARUR-TANJORE	73

In India, the loads are generally in the range of 70 to 90 percent of the transformer rating. Therefore, the loads in each bus are modelled to be 70 percent of the power rating of the step-down transformers connected to each bus. The grid contains a synchronous generator of 400 MVA connected to the PPNALUR bus

3.2.2 COMBINATIONAL ALGORITHM [ ]

$$PI = PI_l + P_{loss} + \frac{1}{m}\sum_{i=1}^{m}|V_i - 1|$$

where

$$PI_l = 1 - \frac{1}{N}\sum_{i=1}^{N}\frac{\omega_i}{\sqrt{2\pi\sigma}}\, e^{-(\frac{(p_i-\mu)^2}{2\sigma^2})}$$

σ = *Standard deviation of Line power*

μ = *70 percent of Nominal power (pu)*

ω_i = *Weighting Factor of line*

N = *Number of transmission lines*

m = *Number of buses*

p_i = *Power of each line (pu)*

P_{loss} = *Loss experienced in the grid*

In order to implement the combinational algorithm, the PST is introduced at each line in the grid individually and at each line, we vary the position of tap from minimum to maximum value and, all the parameters mentioned above are calculated.

This method is based on decreased violation of voltage constraints, reduction of losses, and operation improvement by system load-ability increase. The optimal location for PST installation is defined in a way that the whole system or special region losses are minimized. Usually, losses reduction in a particular region (consisting of some line or consumption centres) is not an appropriate measure and there is no assurance of losses decrement in the entirety of the system. So, considering the combination of the mentioned assumptions and entire losses of the system as the goal function is crucial.

The best location of PST, in this algorithm is determined by the 3 parameters below:

1. $\boldsymbol{PI_l}$ **(system load-ability index):** PI_l is a low value when all the lines are loaded almost nominal. Instead, if system is overloaded, it will be a high value. It should be noted that in order to prevent the states related to overload lines, weighting factors of this lines can be selected lower. In this

study, lines weighting factors are chosen to be unity.

2. **P_{loss}(system loss)**: This parameter shows the losses experienced in the system. The position of the PST is based on the location with lowest losses, relatively.
3. **Voltage Index**: The third parameter lets us choose the PST location based on the line with the best voltage profile.

Interpretation:

1. PI_l (system load-ability index): Lower the value better is the loading
2. P_{loss} (system loss): Lower the value better is the system
3. **Voltage Index**: Lower the value, better the voltage profile of the system.

We can interpret the results in two ways. First, after using the algorithm, we can get the PST locations which alleviate the current overloading, overvoltage situation in the most effective way. And, second, we get PST location which can work best over the whole range of taps.

To determine which location works best over the entire range of taps, coefficient of variance (CV) is calculated for each parameter .CV is determined because the “offset” caused due to the inherent range of values of various parameters can be removed and then, simply adding the CV of various parameters give the best location.

3.2.3 SIMULATION OF TANJORE GRID IN POWERFACTORY

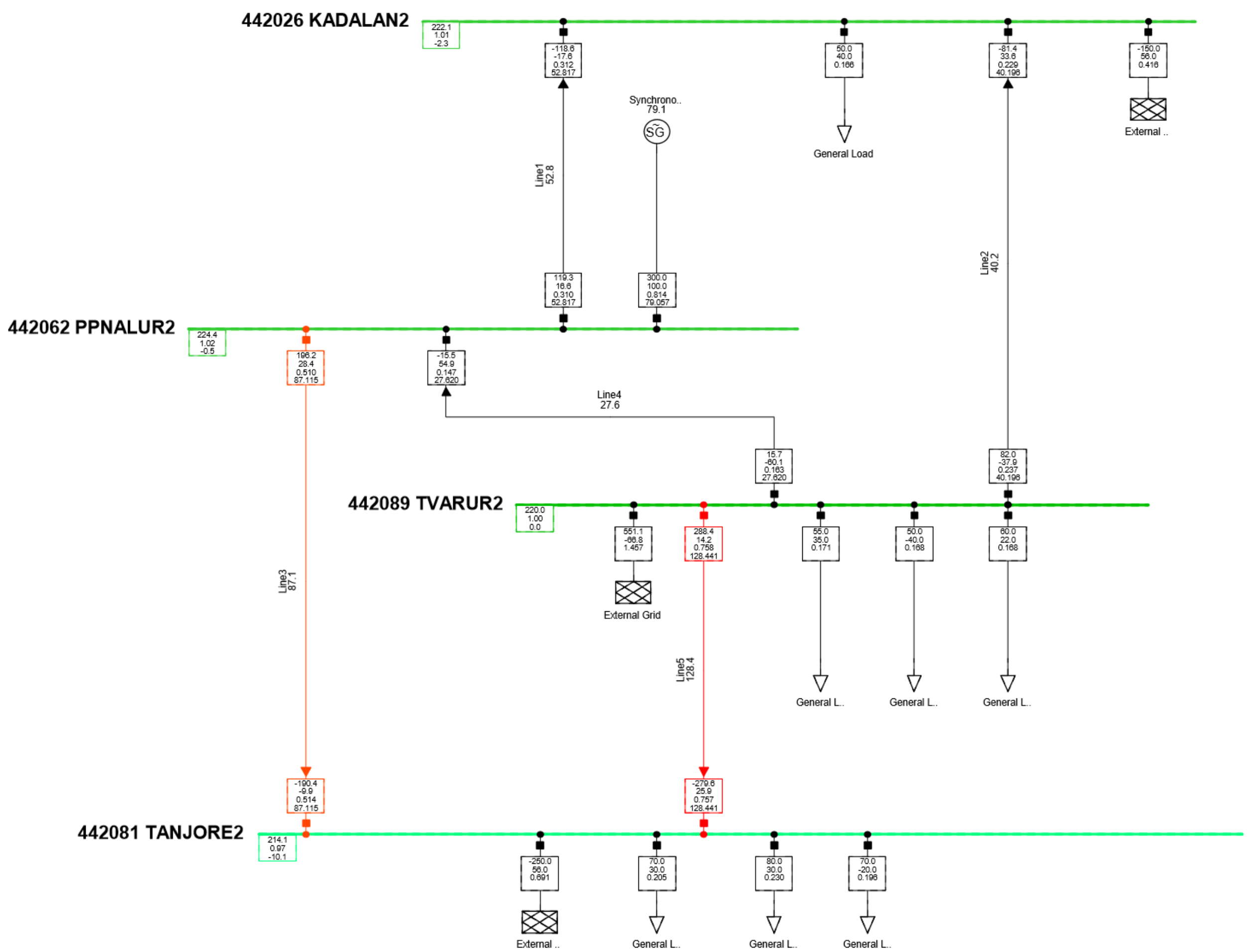


Figure 3.2: Base case simulation of Tanjore Grid without PST

The line loadings are as follows:

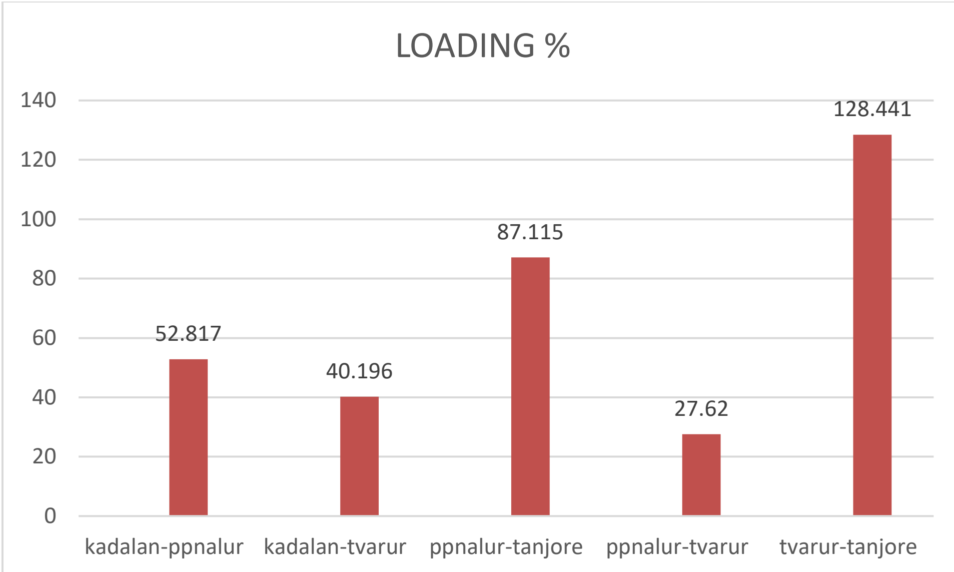


Figure 3.3: Loading percentage of the lines in Tanjore grid

The voltage of the buses in per unit is as follows:

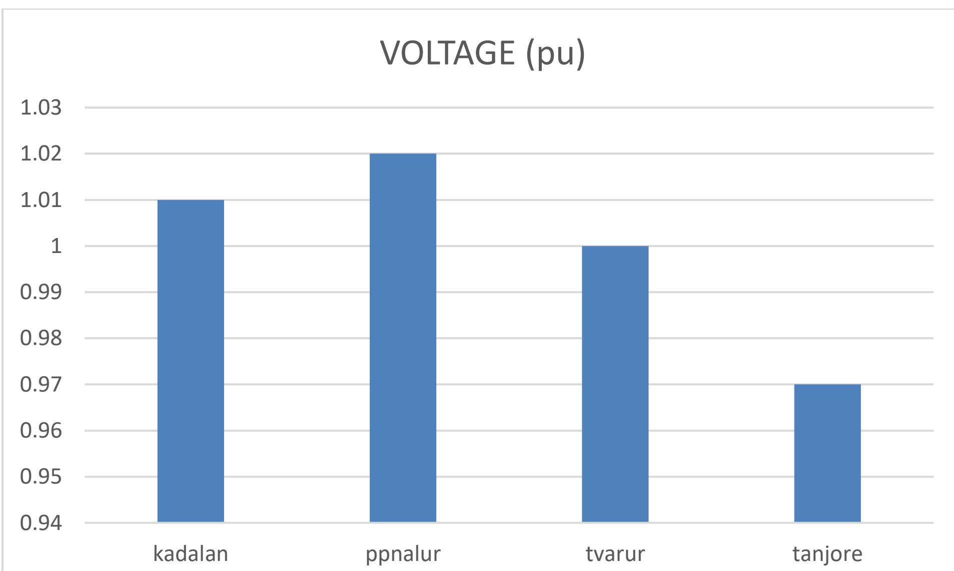


Figure 3.4: Voltage profile of the buses in TANJORE grid

In the TANJORE Grid, there is a total of five lines so there are 5 options for placing the PST. To determine the optimal location, a combinational algorithm is used. This algorithm helps us to find the optimal location out of all the different options.

The algorithm is applied on the current grid in our hands i.e. TANJORE GRID to find the optimal location. We determine the best location separately based on each parameter and then the optimal location by clubbing all the parameters together. We find that TVARUR-TANJORE and PPNALUR-TANJORE experiences overloading of 128.4% and 87.1% from the current rating of the line. Thus, to enhance the current condition of overloading and voltage fluctuation, we will use the Phase Shifting Transformer.

Voltage Limits

$$\text{Voltage index } = \frac{1}{m} \sum_{i=1}^{m=number\ of\ buses} |V_i - 1|$$

The voltage index profile in each line is as demonstrated by the graphs below:

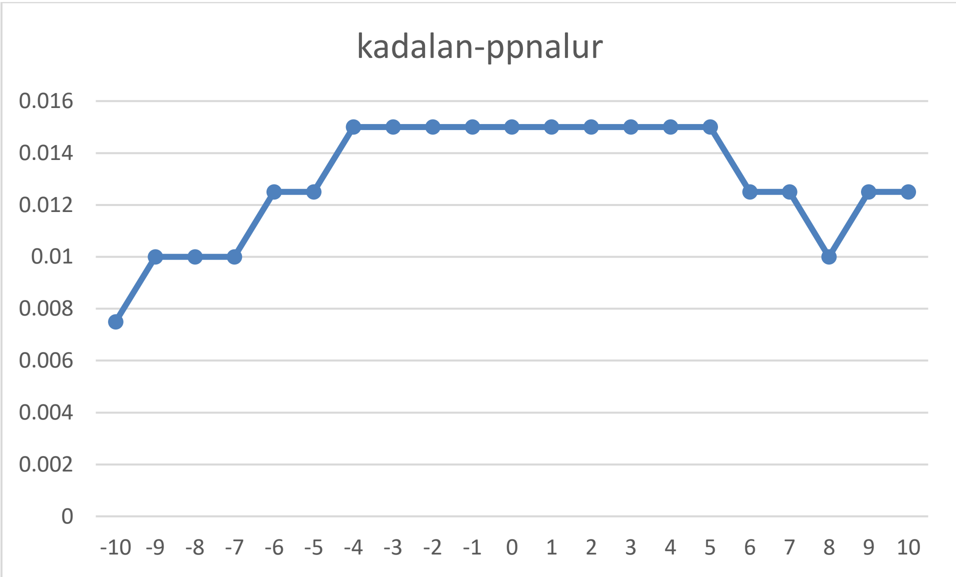


Figure 3.5: Voltage index of KADALAN-PPNALUR

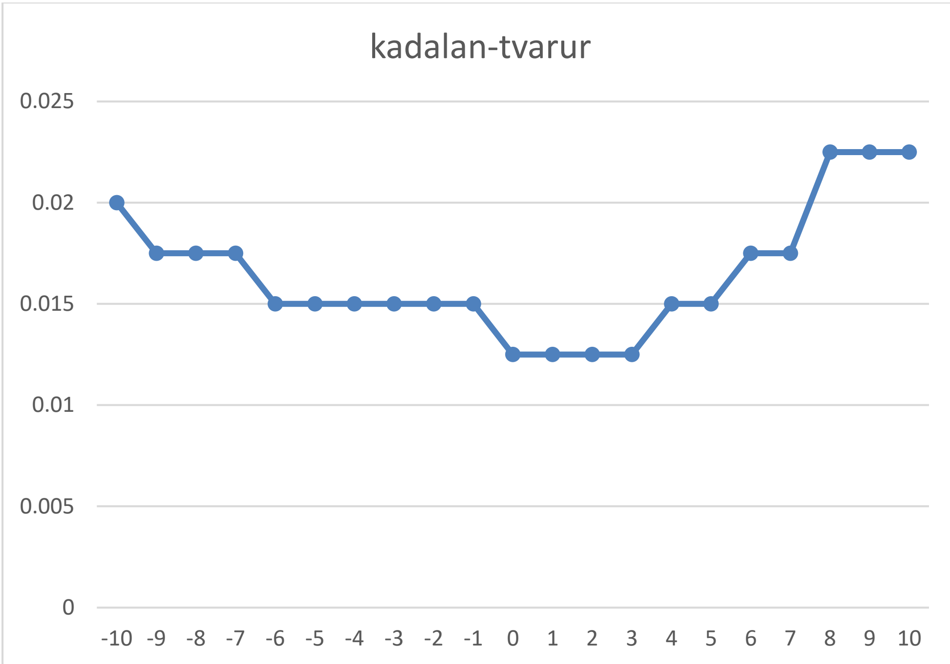


Figure 3.6: Voltage index of KADALAN-TVARUR

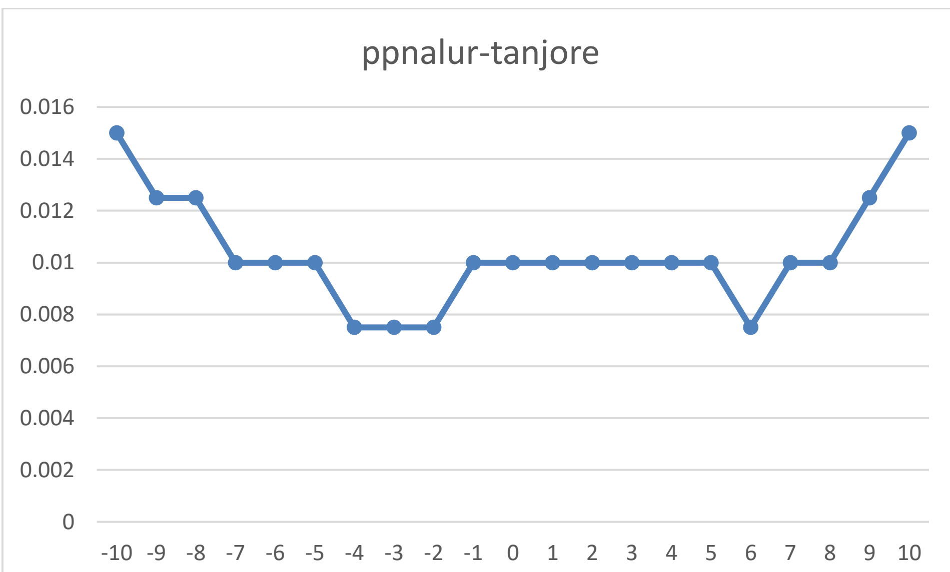


Figure 3.7: Voltage index of PPNALUR-TANJORE

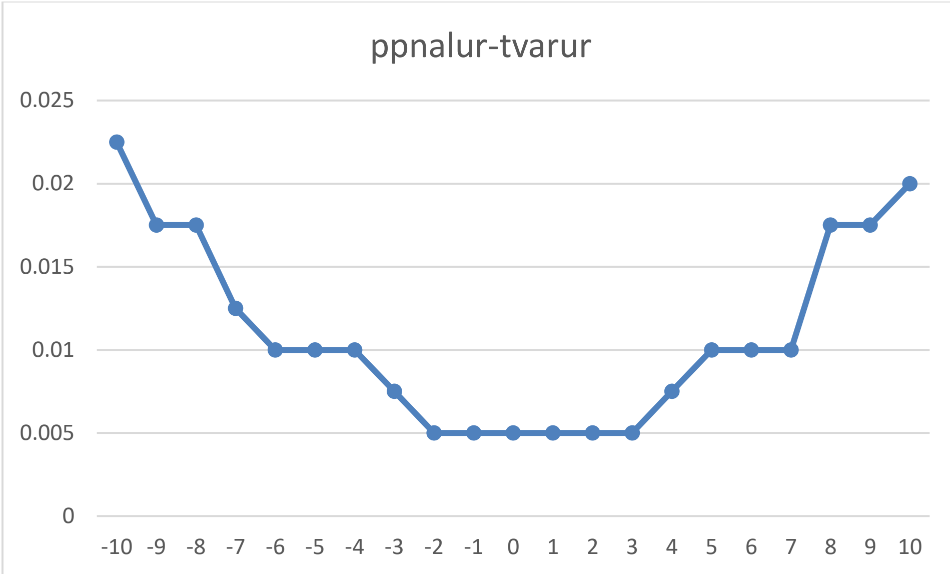


Figure 3.8: Voltage index of PPNALUR-TVARUR

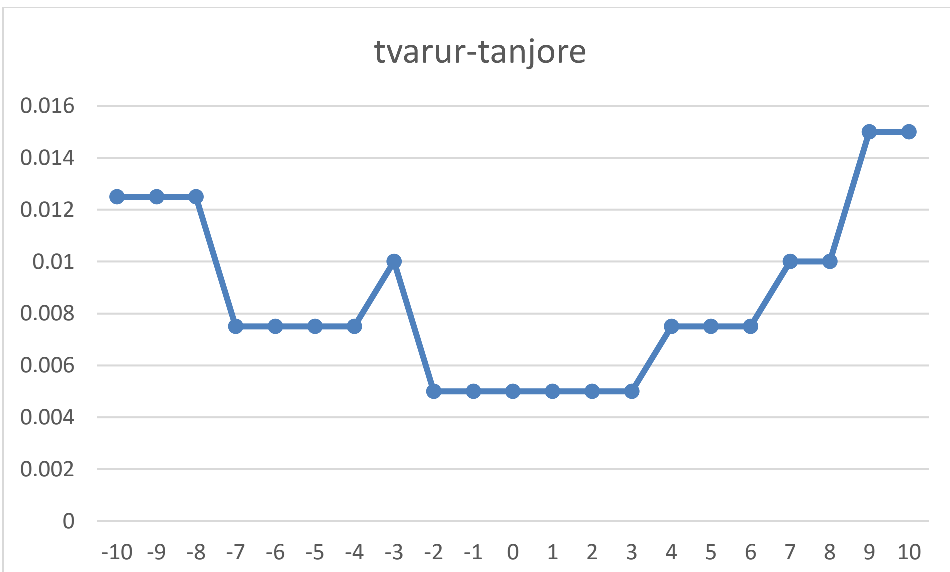


Figure 3.9: Voltage index of TVARUR-TANJORE

In order to get a complete picture, the voltage index profiles of all the lines is plotted on the same graph, the graph is as shown:

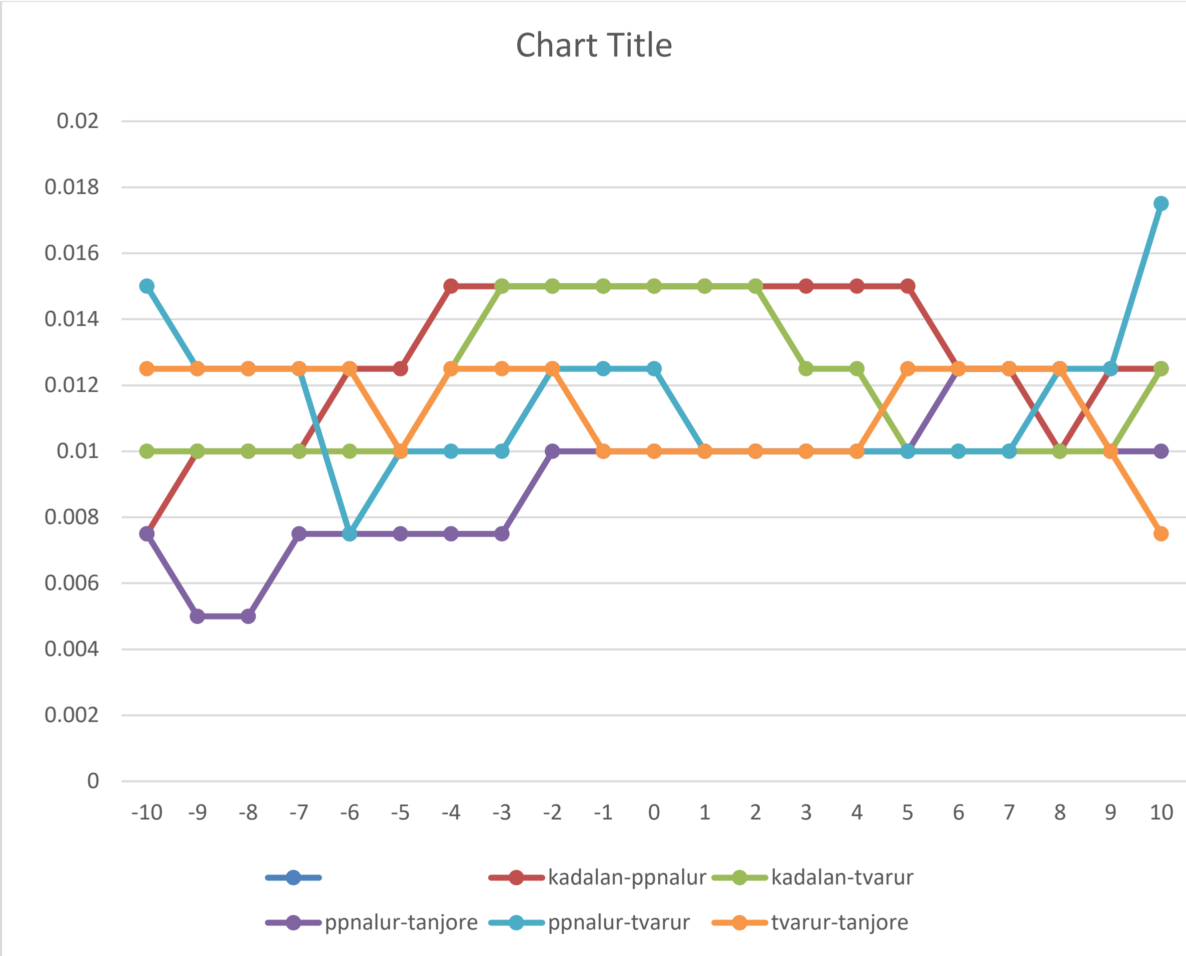


Figure 3.10: Voltage indices of all lines of Tanjore grid

From the graph above we understand that TVARUR-TANJORE line has the lowest deviation from the least value i.e. this line outstands over the whole range of tap positions. So, to enumerate this idea mathematically, we use standard deviation.

And as expected, TVARUR-TANJORE has the least value.

Table 3.2: Standard Deviation of Voltage Profile

KADALAN-PPNALUR	KADALAN-TVARUR	PPNALUR-TANJORE	PPNALUR-TVARUR	TVARUR-TANJORE
0.0134527	0.0175344	0.0083267	0.0052423	**0.0034233**

Therefore, TVARUR-TANJORE is the best PST location in terms of best voltage profile.

System Loss

The System loss index for all the lines over the whole range of tap positions is as shown:

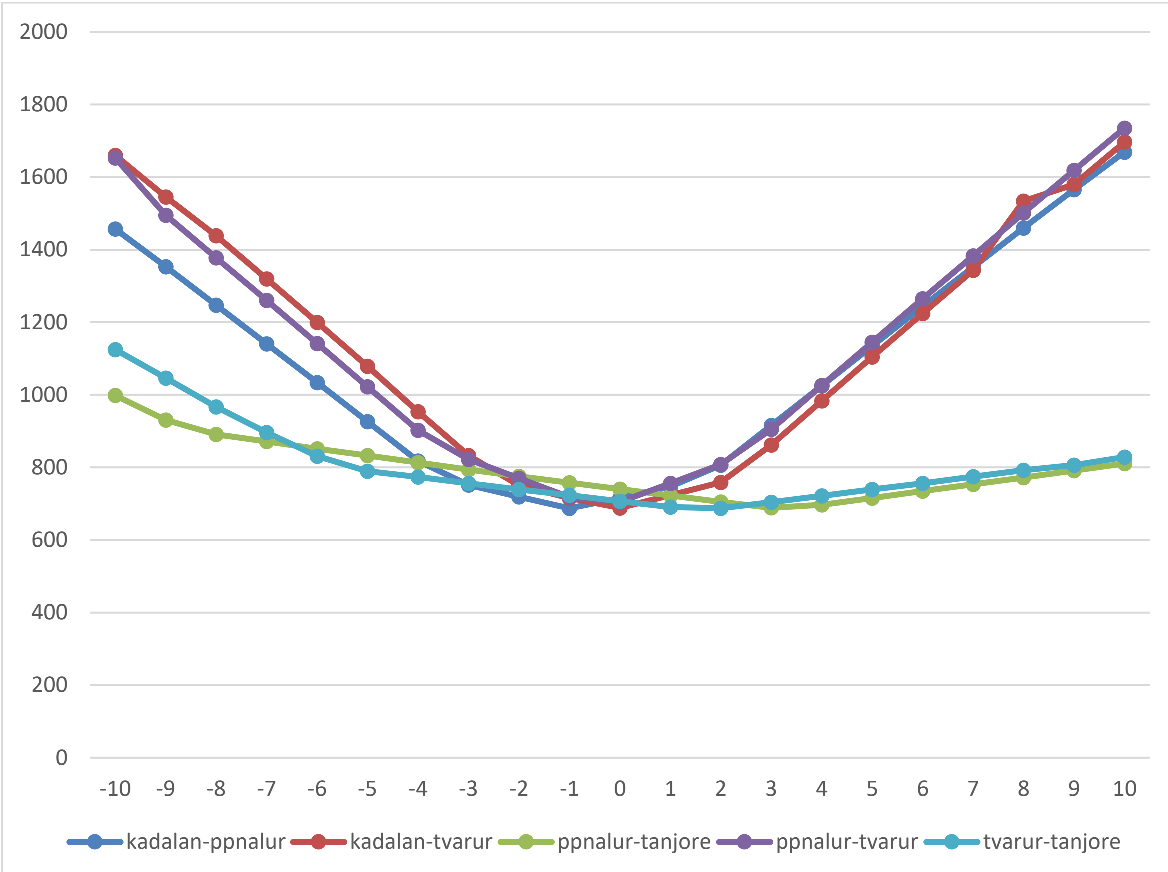


Figure 3.11: System Loss of all lines of Tanjore grid

As we can see above, the minimum value of all the curves has the same 715 MW.

Here we see that the losses of the system increase as the tap position varies, but the line TVARUR-TANJORE has the lowest spread/variance which translates to the best performance, so again we use standard deviation

Table 3.3: Standard Deviation of System Loss

KADALAN-PPNALUR	KADALAN-TVARUR	PPNALUR-TANJORE	PPNALUR-TVARUR	TVARUR-TANJORE
0.0143346	0.0154534	0.0121239	0.0146391	**0.0011242**

And as system losses are taken into consideration, as we anticipated, TVARUR-TANJORE has the lowest value and therefore displays the top performance

System Load-ability

This index helps us determine the PST location depending on the load-ability of the lines, the graph is as shown:

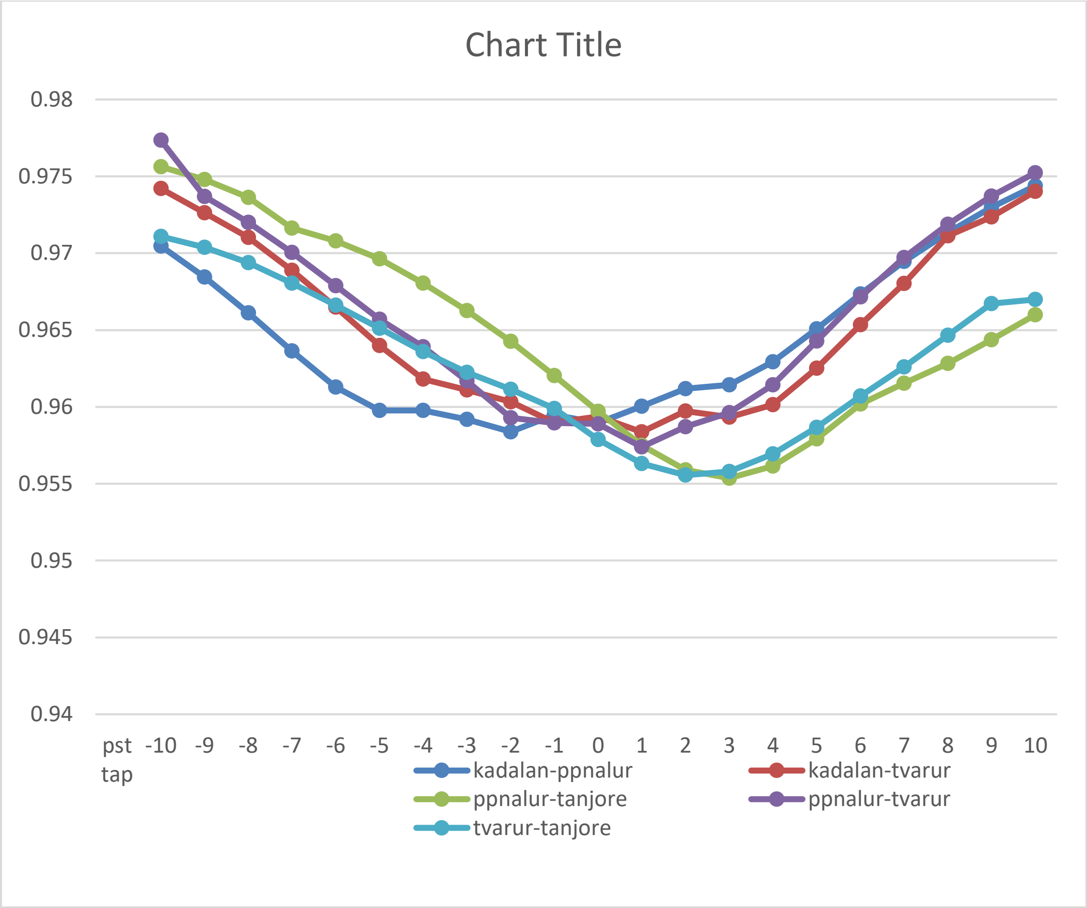


Figure 3.12: System Load-ability of all lines of Tanjore grid

Table 3.4: Coefficient of Variance of System Load-ability index

KADALAN-PPNALUR	KADALAN-TVARUR	PPNALUR-TANJORE	PPNALUR-TVARUR	TVARUR-TANJORE
0.00728343	**0.00584652**	0.00673993	0.00624354	0.00887346

We infer that, KADALAN-TVARUR to be the optimal location in terms of system load-ability**.**

But for alleviating the current overloading, TVARUR-TANJORE is the best line.

3.3 SUMMARY

Graphs are plotted for all the above indices for different tap positions from -10 to 10. In order to determine the optimal location, we can use any index as our system requirements demand. Since, a particular line outstands in more than one system index, it is chosen as the best location.

Therefore, the observations after applying the Combinational Algorithm are:

Table 3.5: Best location for PST w.r.t the three system parameters

INDICES	LINES
PIL	KADALAN -TVARUR
VOLTAGE	TVARUR-TANJORE
P LOSS	TVARUR-TANJORE

From here we see that TVARUR-TANJORE is the best location for PST as it has the lowest value for two indices, namely, Voltage Index and System Loss.

CHAPTER 4

CONCLUSION AND FUTURE SCOPE OF PROJECT

Conclusion

1. In the TANJORE Grid Using the Combinational Algorithm, the overloading that is witnessed during the peak duration can be alleviated

2. The optimal location of PST can be found on the basis of all the three indices

3. A different way to determine the best PST location is found by the usage of coefficient of variance as a tool for comparison

REFERENCES

[1] Energy Statistics 2018, (Twenty Fifth Issue) ,Central Statistics Office, Ministry Of Statistics And Programme Implementation, Government Of India , New Delhi

[2]Power Sector Jan-2017, Ministry of Power, Central Electricity Authority,Government Of India, New Delhi

[3]Electricity Demand Pattern Analysis, Volume 1,Power System Operation Corporation Ltd. 2016

[4]M. Gitizadeh and H. Khalilnezhad, "Phase Shifter Transformers optimum allocation in power systems using a combinational method," 2010 IEEE International Conference on Power and Energy, Kuala Lumpur, 2010, pp. 886-890.

[5] Transmission Plan for Envisaged Renewable Capacity, A Report, Vol-I, Power Grid Corporation of India Ltd., July, 2012

[6] Load Generation Balance Report 2017-18, Government Of India, Ministry Of Power, Central Electricity Authority

[7] Transmission Plan for Envisaged Renewable Capacity, A Report, Vol-II, Power Grid Corporation of India Ltd., July, 2012

[8] Effect Of Renewable Energy Integration On The Voltage Profile Of Indian Power System ,Saranya Agoram MS ,Dept. Of Electrical Engineering, Indian Institute Of Technology – Madras, Chennai, India,