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# Testing Polynomial Load for Voltage Stability

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## ABSTRACT

*Assessment of load models is required in power system voltage stability studies. Voltage stability defines the ability of a power network to maintain steady state voltages at all the buses under both normal operating conditions, and under the state of a disturbance. The research presented as part of this paper, deals with analysis of Impedance, Current and Power static load model for voltage stability studies. The precision of the results are directly related to the load models used in this analysis. The method is analyzed using continuation power flow routine backed by fast decoupled computational iterative approach.. Static var Compensator is used to address the voltage instability caused by the load variations using search procedure. The effectiveness of the proposed method is demonstrated through quantitative simulation on standard IEEE 14 bus system.*

***KEYWORDS:*** *Continuation Power Flow, Search Procedure, Voltage Stability, Polynomial Load*



## I. INTRODUCTION

Voltage Stability or Load Stability is one of the concerns in power systems which are heavily loaded, faulted or having a shortage of reactive power [1]. Load imbalances are one of the many causes of reactive power shortages. During such system disturbances, system stability is imperilled. The probability of moving to the global instability increases. This will usually result in a blackout unless some precautions are considered. The problem of voltage stability concerns the whole power system, although it usually has a large involvement in one critical area of the power system [2]. Power System Load Modeling is a technique used to model the power system and essential for stability assessments. In this paper, we are trying to analyze Impedance, Current and Power static load model also termed Polynomial load for voltage stability studies. Different load models would greatly affect voltage stability aspect of an interconnected power system [4]. We are using continuation power flow backed by BX based fast decoupled load flow to analyze the effects of the above load model and compare the results. Flexible AC Transmission Systems in short FACTS controllers are used to control the variables such as phase angle and voltage magnitude at a given bus and line impedance where a voltage collapse is observed. Introducing FACTS controllers is the most effective way for utilities to improve the voltage profile and voltage stability margin of the system. As the size and the cost of the FACTS devices are high, an optimal location and size has to be identified before they are actually installed.

## II. PROBLEM FORMULATION

Accurate modelling of loads continues to be a difficult task due to several reasons.

Lack of precise information on the composition of the load, changing of load composition with time like day and week, seasons, weather, through time and more influence the load models. Electric utility analysts and their management need evidence of the benefits in improved load representation to justify the effort and expense of collecting and processing load data. Also to modify computer program using load models. The interest in load modelling has increased in the last few years, and power system load modelling has become a new research area in power systems stability [4]. Several studies have reported the critical effect of load representation in voltage stability studies. This leads to identify accurate load models than the traditionally used ones. Though ours is not the first paper to test various static load models for determining the voltage stability limits of a power network, it happens to be a research paper to address stability issues related to polynomial load model or ZIP load model for voltage stability. We present a simple binary search procedure [6] to locate and size static var compensator to address load instability caused by ZIP loads.

## III. MATERIAL

### A. *IEEE 14 Bus Network*

We are testing our load model on IEEE 14 bus power network as shown in Figure 1. The test system consists of twenty one branches, fourteen buses, and eleven loads totalling 259 MW and 81.4 MVAR. The tolerance for bus voltages in P.U. was assumed to be 5%. Bus 1 is assumed slack. The analysis is performed in power system analysis toolbox [5]. We are applying continuation power routine with fast decoupled iterative approach. The number of iteration limit in power flow routine is set to twenty count.

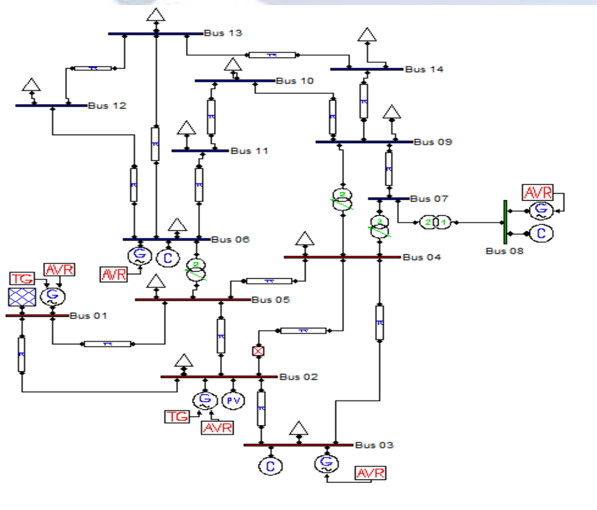


***Figure 1: IEEE 14-bus Network***

### B. *Polynomial Loads*

Constant impedance loads examples: Residential loads and lighting loads such as bulbs to mention a few. Constant current load examples: Transistors, transducers and incandescent lamps. Constant power loads are switching regulators and industrial loads.

### C. *SVC-Static VAR Compensator*

It consists of a capacitor bank in parallel with a thyristor controlled reactor. The schematic is given in figure 2. It is used to stabilize a bus bar voltage and improve damping of the dynamic oscillation of power systems. In this model, a total reactance bSVC is assumed and the differential equation 2.1 holds. The regulator is having an anti-windup limiter. The reactance bSVC is thus locked if one of its limits is reached [3].

$$\dot{b}_{SVC} = (K_r (V_{ref} + v_{POD} - V) - b_{SVC})/T_r$$
$$Q = -b_{SVC}V^2 \qquad (1)$$

Where Kr is regulator gain, Vref is reference voltage and Tr is regulator time constant. SVC model has an additional stabilizing signal vPOD, which is the output of the Power Oscillation Damper.

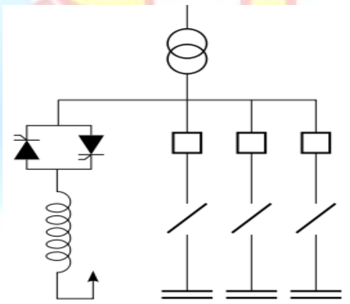

***Figure 2: Structure of SVC***

### A. *Flow chart: Binary Search*

The flow chart for binary search approach is presented in figure 3.

## IV. IMPLEMENTATION, RESULTS & DISCUSSION

The polynomial loads were installed at buses 9 to 14. Here we observe a decline in voltage magnitude as a result of reactive power deficit after installation of ZIP loads as compared to a case without these loads. As can be seen from table 1 and figure 4, we observe an improvement in bus voltage magnitude profile after the placement of SVC using binary search approach. Also, observe similar kind of decline in maximum loading limit before and after placement of ZIP loads. The loading limit is enhanced using placement of SVC in this case to improve the steady state stability limit at the heavily loaded power system buses. For pre-disturbance condition, the loading limit was 1.7086 which was improved to 1.9923.

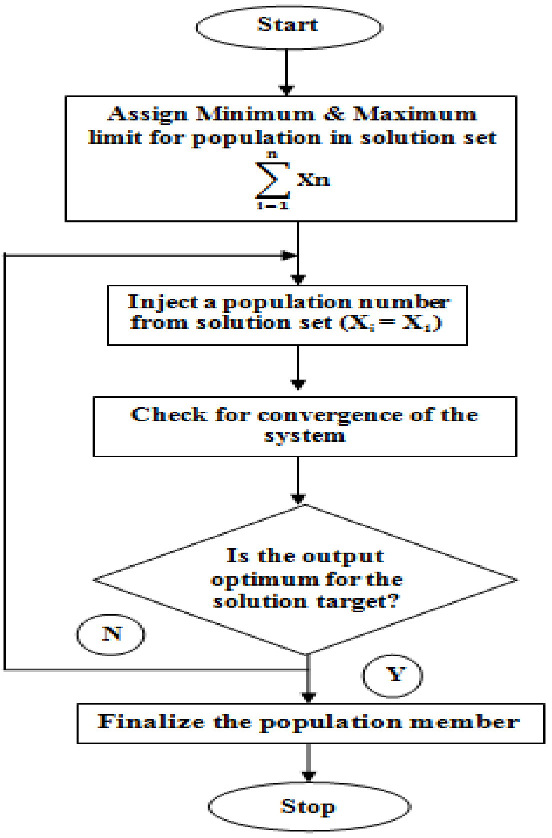


***Figure 3: Binary Search Procedure***

***Table 1: Voltage Magnitude Profile***

| BUS No. | Before ZIP Load | After ZIP Load | ZIP load with SVC |
|---|---|---|---|
| 1 | 1.0576 | 1.0576 | 1.0576 |
| 2 | 0.95357 | 0.90694 | 0.8996 |
| 3 | 0.89545 | 0.79309 | 0.78978 |
| 4 | 0.81763 | 0.76006 | 0.79653 |
| 5 | 0.83132 | 0.78121 | 0.80651 |
| 6 | 0.87874 | 0.84241 | 0.95576 |
| 7 | 0.84196 | 0.81191 | 0.98311 |
| 8 | 0.97488 | 0.95581 | 1.0485 |
| 9 | 0.77609 | 0.7516 | 1.045 |
| 10 | 0.76998 | 0.74653 | 1.0077 |
| 11 | 0.81253 | 0.78398 | 0.97177 |
| 12 | 0.82661 | 0.79661 | 0.92217 |
| 13 | 0.8061 | 0.77917 | 0.9168 |
| 14 | 0.72578 | 0.71082 | 0.93684 |

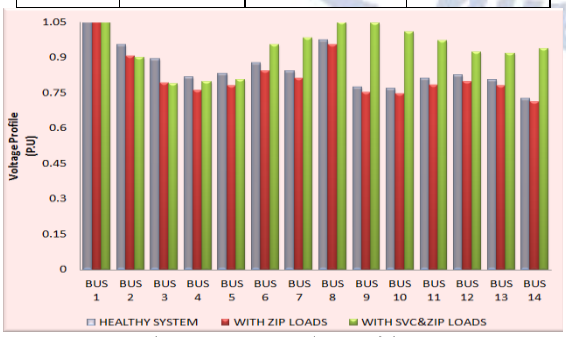


**Figure 4: Voltage Magnitude Profile Comparison**

## V. CONCLUSION

The work presented here details a load model study for voltage stability using Search Procedure. The case study considered was modelled using polynomial static loads and analyzed for their performance in terms of voltage magnitude profile and maximum loading parameter. The inclusion of load models in the power system causes a decline in voltage profile as a result of reactive power deficit. A method is also presented to determine the optimal location and size of SVC to enhance the stability. This method is based on Binary Search. This algorithm is simple in implementing compared to complicated Artificial Intelligence techniques. It is capable of finding multiple optimal solutions, giving more flexibility to make the final decision about the location of the FACTS controller. The future scope of this work deals with the testing of above techniques for higher order IEEE case studies and practical networks.

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