Simulink Approach for Restoration of Depression in Voltage from Rated Level in an Interconnected Power System Due to Overloading Using ANN

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ABSTRACT *The purpose of the paper is to establish restoration of depression in voltage caused by certain levels of overloading of generators in an interconnected power system. This is achieved by way of developing a simulink of Automatic Voltage Regulation wherein the effect of overloading on depression in voltage is realised through increase in load multiplier. Also the restoration of voltage to its rated level is achieved by necessary changes in feedback path gain. Initially the simulink is tested for some known levels of overloading and feedback path gains to achieve restoration against depression in voltage. Next, an ANN is developed and trained on these test results obtained on Simulink. After training the ANN becomes ready to provide all feedback path gains corresponding to unknown levels of overloading. Finally, the results provided by the ANN have been tested on simulink and the simulink gave the restoration of depression in voltage for the given overloading.*

Keywords: *Simulink, Restoration, Depression in Voltage, Rated Voltage, Interconnected Power System, ANN*

1. Introduction

The increase in load leads to voltage drop in synchronous impedance of alternator, transmission lines, transformer impedance, feeders and distributors. This drop in voltage leads to depression in voltage from rated level at the actual load terminals. The problem of depression in voltage due to overloading is a serious threat to the operation and control of the vital machines connected to power system. Due to low voltage the speed of the machine do not remain rated and they cause damage in quality of product. Under the situation it is quiet important that voltage at the device level should be maintained at rated level despite the overloading.

In [1] the authors have proposed a new intelligent approach to facilitate the optimal power flow calculations to be utilised in different control centres. The main advantage of proposed system with real time is to control the system voltage profile in tracing mode. The robustness of the proposed technique lies in improving the voltage violations at different buses. In [4] the authors emphasis the technical and economical merits of power system in interconnection. According to them the system can transmit bulk power over long distances without much voltage drop. It also provides the higher capability to handle extended future power demands.

In [7] the authors have explained specific load flow analysis. The study gives performance and power flows for specified condition when the system operates under steady state conditions. The study is useful for growing demand of power and increasing complexity in power network.

In [10] the authors have worked out power quality analysis and they have reported that the failure of series reactor and 11KV protection monitoring power system component leads to harmonics, transient and other power quality related problems. Two major problems are: (i) voltage sag and (ii) harmonic distortion. In event of voltage sag due to insufficient energy supply the equipment may malfunction or trip. Another disturbance of harmonics introduced by non-linear loads may cause increased power losses and heating. In [13] the authors have shown concern for low power factor conditions caused by inductive loads. Such situations are highly uneconomical and are one responsible for depression in voltage. But, this problem can be controlled by properly designing capacitor bank for power factor improvement automatically ensures restoration of voltage to its rated level.

This paper is organised such that **Section 2** explains development of Simulink for Automatic Voltage Regulation and its testing for increased overloading leading to depression in voltage from rated level. Next, the drop in voltage is recovered by decreasing the feedback path gain in the Simulink. **Section 3** shows the development of ANN on MATLAB which is trained using the test results of Simulink. After training the ANN becomes ready for giving the values of feedback path gains for such overloading which are not known. **Section 4** describes how unknown overloading levels and their feedback path gains as found from ANN is tested on the Simulink and how these test results support restoration of voltage following to its depression. Thus, the proposed work is a kind of automation in voltage regulation achieved through ANN programming. **Section 5** concludes the work and is followed by references.

2. Development of Simulink for Automatic Voltage Regulation and its Testing

A Simulink is developed on MATLAB for Automatic Voltage Regulation(AVR). This is because the voltage is required to be maintained at rated value as and when it becomes low due to increase in load demand. The Simulink is tested for increasing values of load multiplier and it is observed that the voltage is reduced with increase in the load demand. The disturbed state is restored back to normal value, that is 230V by reducing the feedback multiplier. The Simulink developed on MATLAB for the purpose of Automatic Voltage Regulator is as under.

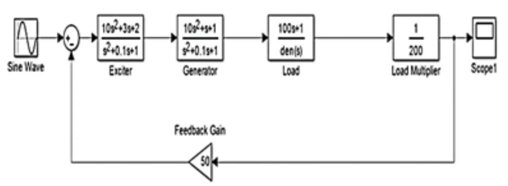

Fig. 1. Simulink for Automatic Voltage Regulation

Testing of Simulink Model

The Simulink was tested for random load multipliers. For each multiplier the value of feedback multiplier was found by way of testing the Simulink. The particular value of feedback multiplier which gave the restoration of disturbed voltage was considered. The test data for standard voltage 230Volts is as given in table 1.

Table 1: Readings of Test data of Simulink for Automatic Voltage Regulation

S.no.	Load Multiplier	Feedback	Output
1	1/200	55	±200
2	1/200	50	±230
3	2/200	50	±100
4	2/200	33	±230
5	3/200	33	±120
6	3/200	26	±230
7	4/200	26	±150
8	4/200	22	±230
9	5/200	22	±180
10	5/200	19	±230
11	6/200	19	±200
12	6/200	17	±230
13	7/200	17	±200
14	7/200	16.5	±230
15	8/200	16.5	±200
16	8/200	16	±230
17	9/200	16	±200
18	9/200	15.5	±230
19	10/200	15.5	±200
20	10/200	15	±230

The monitor outcome of above test results are indicated in following figures. These graphs show the disturbed result due to increase in load and restoration of same due to reduction in feedback multiplier. However out of 20 the first and last test result is shown.

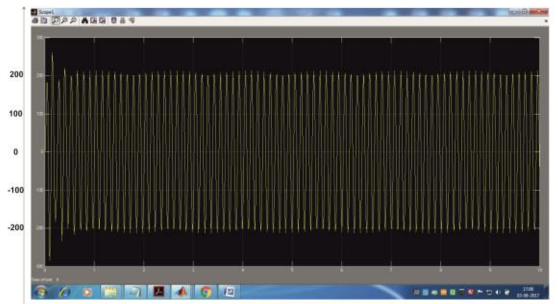

Fig. 2. Disturbed Voltage for Load multiplier 1/200 and Feedback gain 55

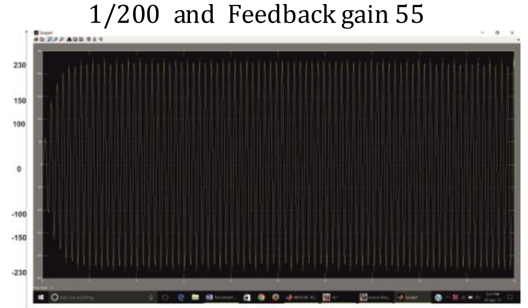

Fig. 3. Restored Voltage for Load multiplier 1/200 and Feedback gain 50

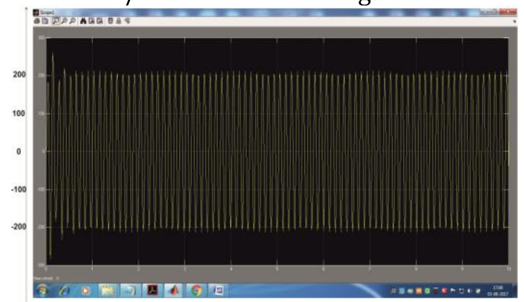

Fig.4. Disturbed Voltage for Load multiplier 10/200 and Feedback gain 15.5

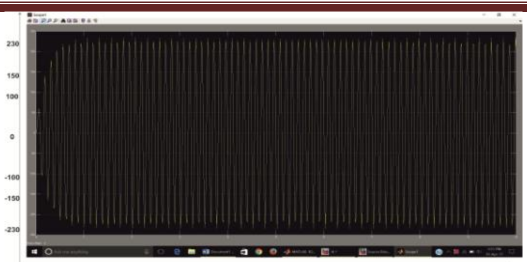

Fig.5 Restored Voltage for Load multiplier 10/200 and Feedback gain 15

This is for certain known levels of overloading with corresponding feedback gain for restoration. This data is used for training ANN to predict for unknown levels of load.

3. Development of ANN for Restoration of Depression in Voltage from Rated Level Due to Overloading

An ANN has been developed for knowing the outcome of Simulink without testing it, but by testing ANN only. For the purpose the ANN is trained by test results of Simulink data. The ANN program is as under; it is followed by its testing. The ANN program for Automatic Voltage Regulator is as under

```
a= 0.005:0.005:0.05;
b=[50; ...
33; ... .......
..........
16; ...
15.5; ...
15];
c=b';
p=[a aaaaaaaaaaaa a];
t=[c cccccccccccc c];
net=newff(p,t,5);
net=train(net,p,t);
y=sim(net,a);
gensim(net)
```

The ANN is trained on Simulink data and the ANN model its training performance and regression plots are shown in Fig. 6, Fig. 7 and Fig. 8 respectively.

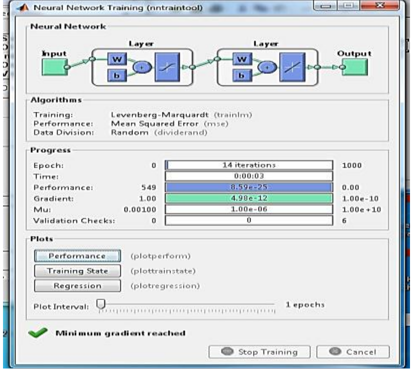

Fig.6. ANN for Automatic Voltage Regulation

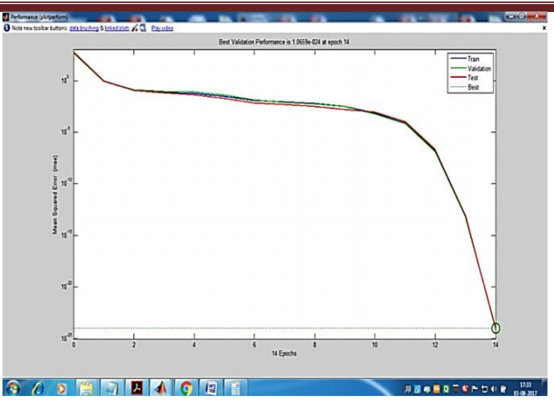

Fig.7. Performance of ANN

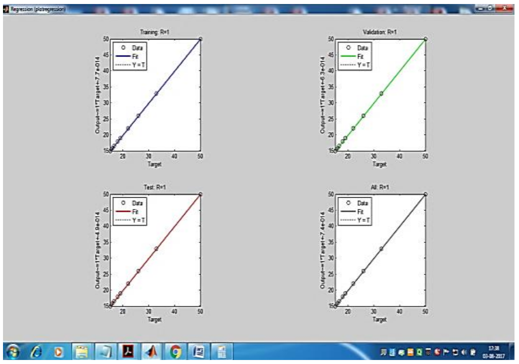

Fig.8. ANN Regression

4. Outcomes of ANN for Some Unknown Levels of Overloading of Voltage

The ANN suggested 20.2 as feedback value for 4.5/200 load multiplier. The voltage of 230 V was restored on value 20.2 as shown in following figures.

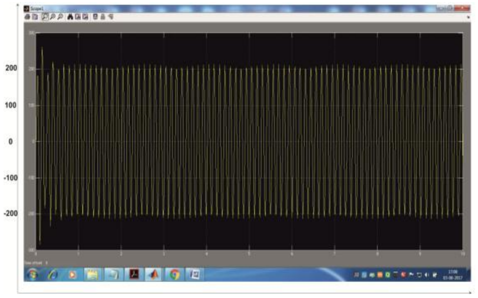

Fig.9. Disturbed Voltage for Load multiplier 4.5/200 and Feedback gain 22

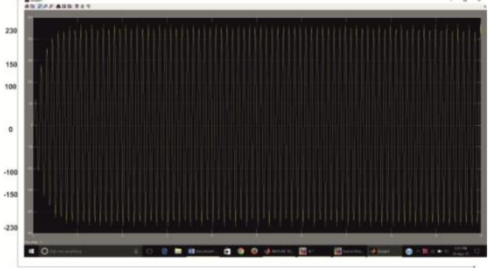

Fig. 10. Restored Voltage for Load multiplier 4.5/200 and Feedback gain 20.2

The test results indicate the effect of overloading leading to depression in voltage. But, when the control is applied via feedback multiplier as per the suggestions of Neural Network it is possible to restore back the voltage to normal value corresponding to unknown level of load multiplier.

This approach saves us from real time loading and facing adverse consequences on voltage. The expected depression in voltage is pre – visualised and control action is confirmed by testing the effect of feedback gain (suggested by ANN) upon the restoration of voltage to its rated standard.

5. Conclusion

The depression in voltage from Rated Voltage Level which results from overloading has been simulated on MATLAB for an interconnected power system. Also a Simulink has been developed which provides the information about the depression in voltage from its rated level due to overloading. Next the feedback gain is changed such that the depression in voltage is removed and the rated level of voltage is restored. This exercise provides us a set of data regarding overloading, the effect of overloading on voltage and its control. Using this data we have trained an ANN which is based on knowing the feedback gains which provides restoration of voltage against some unknown levels of overloading levels. Later, these feedback gains and the corresponding unknown levels were tested on Simulink which also confirmed the restoration of voltage followed to its depression caused by overloading.

The contribution of the paper includes development and testing of Simulink for Automatic Voltage Regulation. Also the ANN programming helps to provide feedback with gains for unknown levels of overloading. Next the new feedback path gains corresponding to unknown levels of overloading when tested on Simulink gave restoration of depression in voltage back to rated voltage level. This substantiates the working of ANN.

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