



An Energy Based Fuzzy Logic Dc-Link Voltage Controller For Three Phase DSTATCOM To Compensate AC Loads

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Abstract----- it is very important to compensate the transient response of DSTATCOM for unbalanced and nonlinear loads. Majorly the dc link voltage will be varied, when any small change in the load side. The proper operation of DSTATCOM is achieved with the help of the proportional integral controller (PI) is used. But the transient response of this controller is slow, Because the multiplication of the gains are more In this paper implement the energy based fuzzy logic controller with fast reference voltage generation to regulate Unbalance voltage in three-phase system. Also improves the Power Quality of the 3-phase unbalanced and nonlinear loads. One of the main advantages of Fuzzy control over conventional controller is the inaccuracies of the sensors on the system performance can be reduced by adding additional rules, this reduces the need for costly sensors and cost of the control system is reduced without a compromise in performance. The simulation results show a very good performance

Index Terms—DC-link voltage controller, distribution static compensator(DSTATCOM), harmonics, power quality (PQ), fuzzy logic, power factor

I.INTRODUCTION

In general the power system network consists of unbalanced and nonlinear loads. These loads are creates majorly power quality problems in the network. Power quality will be depends upon the voltages and currents, due

to these currents causes a overheating of the machine. and they causes poor power factor, voltage interference and more harmonic distortion .to overcome those problems in power system network we are implementing the custom power devices they are UPFC,SSSC, DSTATCOM. Generally DSTATCOM device is used because it should have shunt controlling technique. The flexible ac transmission system allows a greater control of power flow and a secure loading of transmission lines to levels nearer to their thermal limits, among other benefits.

To mitigate the PQ problems in the load conventional DSTATCOM is preferred.and to supply the dc loads from its dc link as well. The rating and design of the VSI decides the sharing if the ac and dc bus. The DC link with this DSTACOM supports instantaneous compensation along with it supplies dc loads also.

However, when the dc link of the DSTATCOM supplies the dc load as well, the corresponding dc power is comparable to the average load power and, hence, plays a major role in the transient response of the compensator. Hence, there are two important issues. The first one is the regulation of the dc-link voltage with in prescribed limits under transient load conditions. The second one is the settling time of the dc-link voltage controller. Conventionally, a PI controller is used to maintain the dc-link voltage

In this paper, an energy based fuzzy logic voltage controller based on the dc-link capacitor energy is proposed. The detailed modeling, simulation, and

experimental verifications are given to prove the efficacy of this energy based fuzzy logic controller.

II. COMPENSATION OF AC AND DC LOADS BY USING DSTATCOM

Due to the simplicity, the absence of unbalance in the dc-link voltage and independent current tracking with respect to other phases, a 3-phase H-bridge VSI topology is shown in Fig. 1

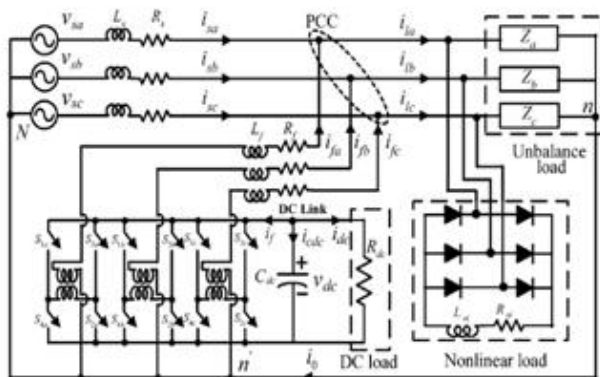


Fig.1 H-bridge VSI topology-based DSTATCOM for Three-phase compensated system

The above figure shows a three-phase, four-wire compensated system using an H-bridge VSI topology-based DSTATCOM compensating unbalanced and nonlinear ac load. In addition to this, a dc load is connected across the dc link. The DSTATCOM consists of 12 insulated-gate bipolar transistor (IGBT) switches each with an antiparallel diode, dc storage capacitor, three isolation transformers, and three interface inductors. The star point of the isolation transformers is connected to the neutral of load and source. The Fig.1 Three-phase, four-wire compensated system using the H-bridge VSI topology-based DSTATCOM. H-bridge VSIs are connected to the PCC through interface inductors. The isolation transformers prevent a short circuit of the dc capacitor for various combinations of the switching states of the VSI. The inductance and resistance of the isolation transformers are also included in and the source voltages are assumed to be balanced and sinusoidal. While compensating, the DSTATCOM maintains the balanced sinusoidal source currents with unity power factor and supplies the dc load through its dc bus.

During normal condition the source is going to generate balanced and sinusoidal voltage. If there is a sudden decrease/increase of the unbalanced and nonlinear load in this type of system, it causes unbalance and harmonics in the load current [4], [5]. These currents are going to be injected at the PCC with the help of DSTATCOM. The operation of the compensator is supported with the help of the dc capacitor and this supplies the required dc load [6] [7].

III. MODELING OF THE DSTATCOM

A DSTATCOM consists of a three-phase voltage source inverter shunt-connected to the distribution network by means of a coupling transformer, as depicted in Fig.2 Its topology allows the device to generate a set of three almost sinusoidal voltages at the fundamental frequency, with controllable amplitude and phase angle. In general, the DSTATCOM can be utilized for providing voltage regulation, power factor correction, harmonics compensation and load leveling [3]. The addition of energy storage through an appropriate interface to the power custom device leads to a more flexible integrated controller. The ability of the DSTATCOM/ESS of supplying effectively extra active power allows expanding its compensating actions, reducing transmission losses and enhancing the operation of the electric grid.

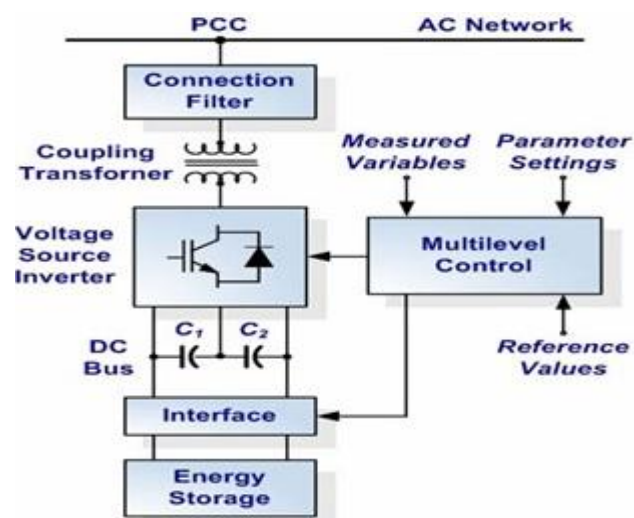


Fig.2 Basic circuit of a DSTATCOM

To calculate the system actual currents, with the help of the proposed DSTATCOM current controllers is as shown below.

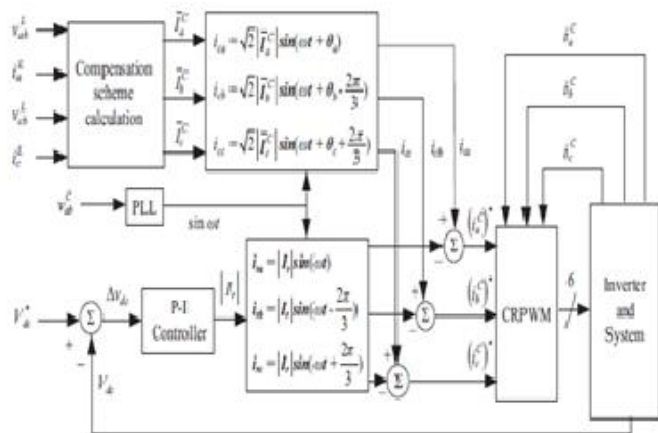


Fig. 3 Block diagram of the proposed DSTATCOM controller currents

In order to keep the dc-link voltage of the inverter in the DSTATCOM at an assigned level during operation, the DSTATCOM needs to absorb active power from the power source to supply the power losses and charge the dc-link capacitor in the DSTATCOM. Hence, use of a Proportional-Integral type feedback controller in the DSTATCOM controller regulates the active current $|I_r|$ of the DSTATCOM [13], and three phase currents are required for comparison of base currents. The resultant will be fed to the controllers in the form of voltages. These currents are achieved with the help of following diagram as shown in fig.3

IV. DESIGN OF A FUZZY LOGIC CONTROLLER

The design of Mamdani type Fuzzy PD controller using Fuzzy Logic tool box in MATLAB is demonstrated [8]. The membership functions of input (error and rate of change of error) and output variables (control action) and rule base are defined in the tool box. The PI controller block in the control scheme of the DSTATCOM was replaced by the designed Fuzzy Inference System (FIS). The DSTATCOM was then simulated for the same load with all other parameters maintaining the same.

A. Fuzzy Control Scheme For D-Statcom

Fuzzy logic (FL) controller is the heart of fuzzy set theory; the major features are the use of linguistic variables

rather than numerical variables. This control technique relies on human capability to understand the systems behavior and is based on quality control rules. Fuzzy Logic provides a simple way to arrive at a definite conclusion based upon vague, imprecise, noisy, ambiguous, or missing input information.

The structure of an FLC is represented in Fig.4 and comprises of four principal components

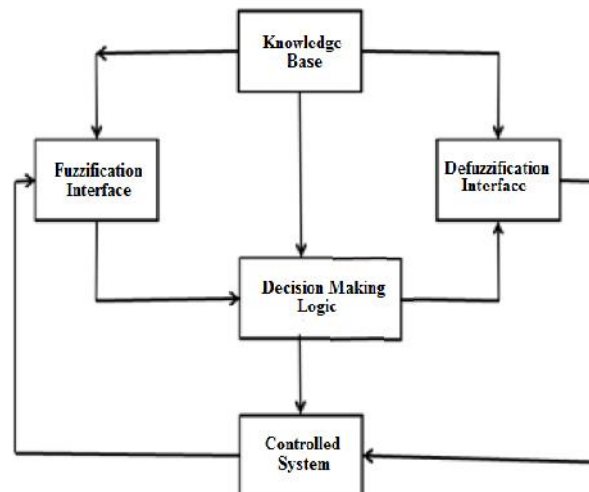


Fig.4 Basic structure of fuzzy logic controller

- The Fuzzification interface will convert input data into suitable linguistic values.
- The Knowledge Base consists of a data base with the necessary linguistic definitions and control rule set.
- A Decision Making Logic will, simulating a human decision process, and interface the fuzzy control action from the knowledge of the control rules and the linguistic variable definitions.
- Defuzzification interface yields a non-fuzzy control action from an inferred fuzzy control action.

B. MEMBERSHIP FUNCTIONS

The input and output membership functions and the rule base are shown below

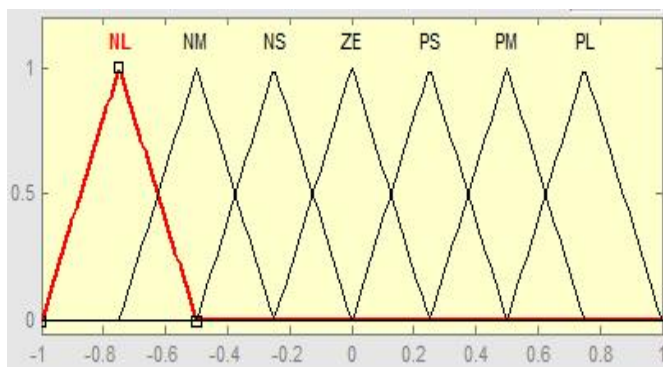


Fig. 5: Error as input

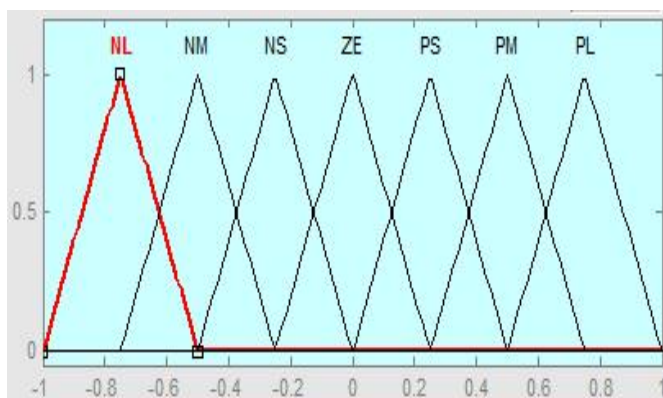


Fig. 6: Change in error as output

In this fuzzy logic controller rules are designed based on the membership functions. Those rules are represented with following notations and rules are arranged in Table.1 as shown in bellow

The two inputs were represented by sets of seven membership functions and expressed in linguistic values as negative large (NL), negative medium (NM), negative small (NS), zero (ZE), positive small (PS), positive medium (PM), and positive large (PB). The range for the “error” input was set and that for “change of error” was set .The AND method used during interpretation of the IF-THEN rules was “min” and the OR method used was “max.” Also, “min” was used as the implication method whereas the “max” method was used for aggregation [9], [10]. The 49 fuzzy IF-THEN weighted rule base was designed to maintain the capacitor voltage constant by providing the required reference current amplitude.

TABLE1 FUZZY RULE BASE

C.F							
E							
NL	NL	NL	NL	NM	NM	NS	ZE
NM	NL	NL	NM	NS	NS	ZE	PS
NS	NL	NM	NS	NS	ZE	PS	PM
ZE	NM	NS	NS	ZE	PS	PM	PL
PS	NM	NS	ZE	PS	PS	PM	PL
PM	NS	ZE	PS	PS	PM	PL	PL
PL	ZE	PS	PM	PM	PL	PL	PL

V.SIMULATION STUDIES

To analyze the performance of system we have designed a Matlab/Simulink model as shown in the fig. Here a three phase source is connected to the unbalanced load and non-linear load, the dstatcom is connected in shunt at the point of common coupling. The main intention here is to control the dc-link voltage. Whenever if there is any change in load, this causes the variation in the dc-link voltage from its reference value. In order to bring back the dc-link voltage to its reference value here we are considering three cases (i) DC-link voltage control with conventional PI controller (ii) DC-link voltage control with Energy based PI controller (iii) DC-link voltage control with Energy based Fuzzy Logic controller. On these three conditions we are getting the variation of dc-link voltage at t=0.4 sec and at t=0.8 sec. The explanation of control circuit and the simulation results are as follows.

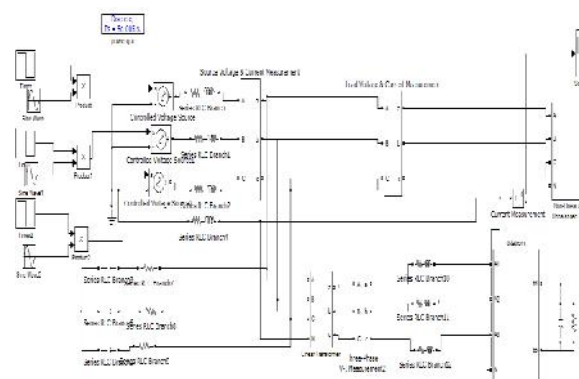


Fig. 7 Simulink diagram of the system with D-STATCOM

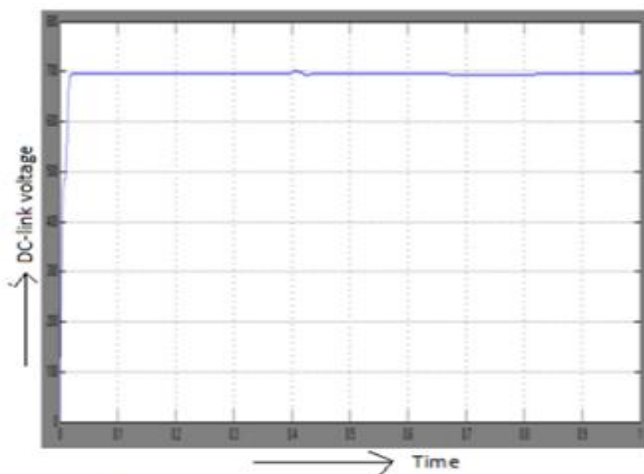


Fig. 11 DC-link voltage with fuzzy controller, transient response improved by $t=0.02$ sec

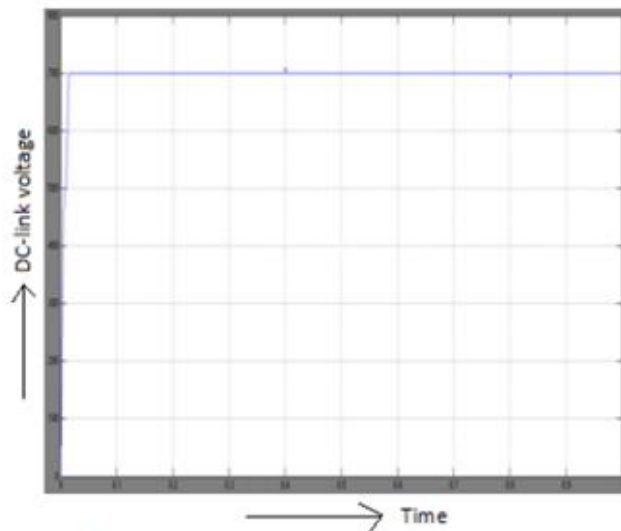


Fig. 13 DC-link voltage with fast acting fuzzy controller, transient response improved by $t=0.002$ sec

C.DC-Link voltage control with Energy based Fuzzy controller:

Here we are taking the square of the dc voltage and its reference and the resultant after comparing these two is passed through the fuzzy controller. Then the dc load power is calculated. Here also we will consider the same two cases as above. By using the energy based fuzzy controller here we are bringing the voltage to its reference value in 0.002 sec after the changes in load.

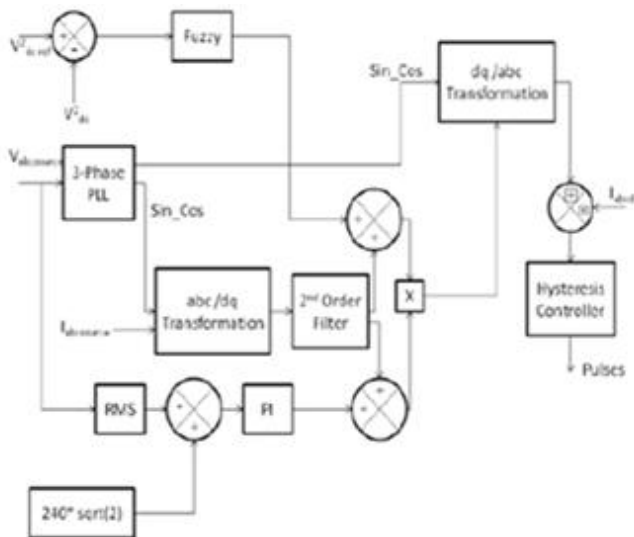


Fig.12 Simulink diagram of the system with Energy based Fuzzy Controller

VI COMPARISION

The below fig.14 shows that comparison between dc link voltages for compensating variation of loads. In above, graph1 (refer fig.9) represents the settling time is 0.42sec.graph 2 (refer fig.11) represents the settling time is 0.402sec. Graph 3 (refer fig.13) represents the settling time is 0.4002sec. The conclusion of the above graph is energy based fuzzy control is better one and it has improvement of power factor is 0.98 that is shown in below

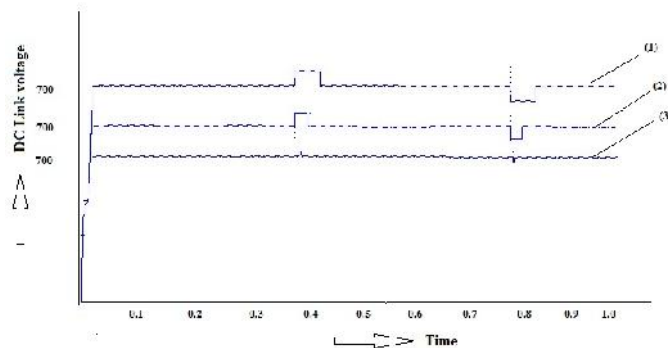
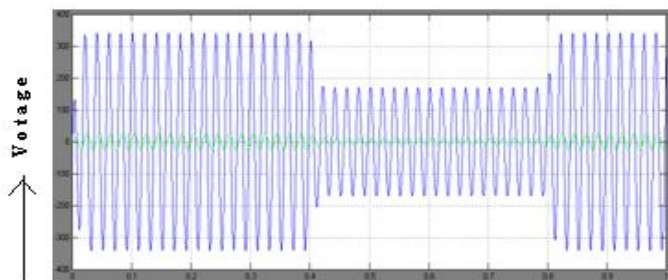


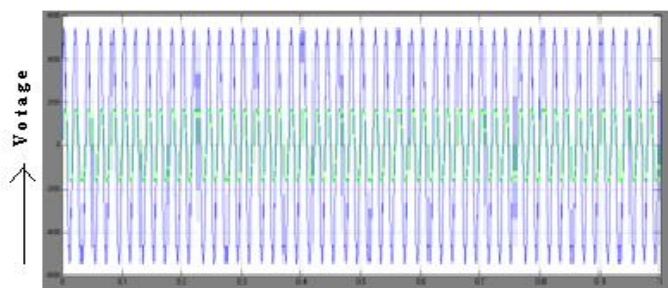
Fig.14 comparison of dc link voltages for three different controllers.

Power factor improvement for PI controller and fuzzy logic controllers is as shown

bellow



Time
Fig.15 Power factor for PI controller



Time
Fig.16 Power factor for Energy based FUZZY controller

Fig. 17, 18, 19 shows the FFT analysis of the load voltage for conventional PI, Energy based PI and with Fuzzy Logic controllers. The comparison table between different controllers is shown below.

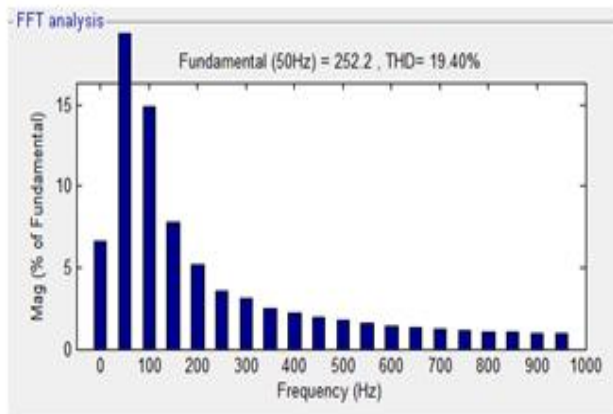


Fig. 17 Total Harmonic Distortion of 19.40%

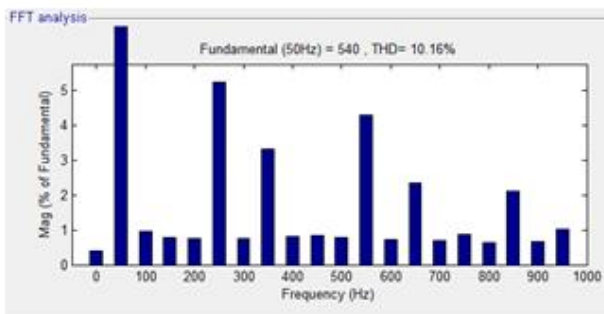


Fig. 18 Total Harmonic Distortion reduced to 10.16%

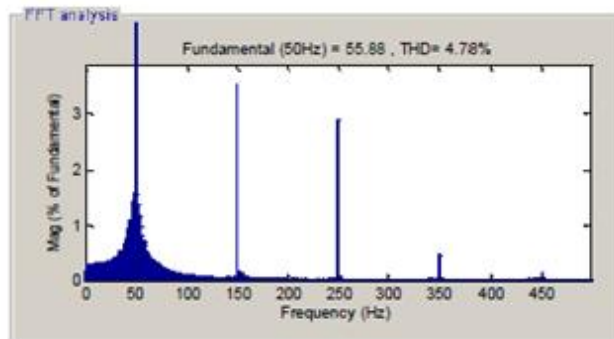


Fig. 19 Total Harmonic Distortion reduction to 4.78%

VII. CONCLUSION

Utilities are finding it difficult to maintain the power quality at the consumer end, and consumers are paying the penalties indirectly in the form of increased plant downtimes, etc. The Shunt connected Custom Power device DSTATCOM can compensate for unbalanced and nonlinear load currents. An energy based d.c link voltage controller is very efficient in improving the Power Quality. A fuzzy controller with fast reference voltage generation to regulate Unbalance voltage in three-phase system improves Power Quality even further. One of the main advantages of Fuzzy control over conventional controller is the inaccuracies of the sensors on the system performance can be reduced by adding additional rules, this reduces the need for costly sensors and cost of the control system is reduced without a compromise in performance. The rule base and membership function of input and output variables can be obtained easily if we have expert knowledge of the system. The simulation results show a very good performance of the method and the control scheme under arbitrary fault conditions of the utility supply. Simulation results shown that system limits

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