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ENHANCEMENT OF PRODUCTION CAPACITY OF TOMATO YIELDS IN GREENHOUSE USING MODEL PREDICTIVE CONTROLLER

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Abstract: The low production of tomatoes in a greenhouse has reduced the financial status of those concerned and the country at large. This can be achieved by introducing an enhanced production capacity of tomato yield in greenhouse using Model Predictive Controller (MPC). This research work was done by characterizing and modeling tomato yield in normal weather condition with respect to temperature, humidity, soil moisture and quantity of tomatoes. Training an Artificial Neural Network (ANN) in a default tomato temperature, relative humidity and soil moisture to attain standard range that will boost its yielding capacity was done. Hence, the trained ANN in a default tomato temperature, relative humidity and soil moisture was integrated into a conventional and Simulink models for model predictive controller to attain standard range that will boost yielding capacity of the tomatoes. The result obtained from the conventional model was the quantity of tomatoes produced in a greenhouse which was 35 tons. On the other hand, when Model Predictive Controller (MPC) was incorporated into the system, it boosts the quantity of tomatoes to 42.7 tons. With these results obtained, it shows that the percentage improvement in the production of tomatoes in a greenhouse when MPC was integrated in the system was 22%. It was thus concluded that Model Predictive Controller enhanced production capacity of tomato yields in the greenhouse

Keyword: Production Capacity Enhancement; Tomato; greenhouse; model predictive controller; Artificial Neural Network; etc.

I. INTRODUCTION:

Low production capacity of tomato in a greenhouse has reduced the financial proficiency of some agriculturist that solely depended on tomato plantation as their only source of income. To surmount this miserable situation of low tomato production in a tomato plantation there is an introduction of an enhanced production capacity of tomato yield in greenhouse using Model Predictive Controller. It is an imperative to know that Model Predictive Control (MPC), also known as Moving Horizon Control (MHC) or Receding Horizon Control (RHC), is a popular technique for the control of slow dynamic systems, such as those encountered in chemical process and flow control in petrochemical, in agriculture, gas pipeline control, waste heat, pulp and paper industries

(Rismayasari *et al*., 2009), and active vibration control of railway vehicle (Orukpe *et al*., 2008). The cure causes of low productivity of tomato yield are when the temperature, relative humidity and soil moisture are not within the standard specified range of tomato growth and yield.

The world population is on the increase even with a declining growth rate (Egharevba, 2009; Okolotu and Oluka, 2021; Okolotu, 2024; Okolotu *et al*., 2024a). Thus is the demand for improved yields in food production like tomatoes which are usable in various form ranging from raw, steamed, processed, cooked, fried, *etc*. The need for production of agricultural processed food produce abound (Okolotu *et al*., 2024b). This is because in processed form it can last longer.

Tomato: Tomato is one of the most important vegetable crops produced by farmers in Nigeria with a demand gap of 2.3 million tons (Olaniyi *et al*. 2010; FMARD, 2015; Olatunji and Akeem, 2022). It is a fruit vegetable produce. It is the world's second – largest vegetable crop following potato, and it is the most canned vegetable (Olatunji and Akeem, 2022). Demand for tomatoes is usually strong because of the vine – ripe nature and general overall high level of eating quality (Hochmuth G.J., 2021). Tomato production in Nigeria requires serious attention as the demand for domestic and industrial use has brought about peak rates in recent times (Olatunji and Akeem, 2022). The demand is relatively high worldwide. Computers can control many mechanical devices within a greenhouse (vents, heaters, fans, evaporative pads, CO2 burners, Irrigation valves, fertilizer injectors, shade cloths, energy – saving curtains) based on preset criteria, such as temperature, irradiance, humidity, wind, and CO2 levels (Olatunji and Akeem, 2022).

Greenhouse: A greenhouse is a specialized controlled environmental structure that is made almost entirely out of polycarbonate or glass. This allows the building to trap sunlight with great efficiency and hence has positive benefits for the growth of crops. Within a greenhouse, a large number of variables can be closely controlled and monitored. This includes temperature, humidity, moisture, sunlight, *etc*.

II. MATERIALS

The main material used in this research is the study area (Agricultural engineering department demonstration site in delta state university of science and technology Ozoro). Other materials used include: Greenhouse, Simulink model, Artificial Neural Network, tomatoes, *etc*.

III. METHODOLOGY

The research methodology carried in this work was to characterize and model tomato yield in normal weather condition with respect to some characteristic metrics, training ANN in a default tomato temperature, relative humidity and soil moisture that will attain standard range in order to boost its yielding capacity. Integrating the trained ANN in a default tomato temperature, relative humidity and soil moisture into a Simulink model for Model Predictive Controller to attain standard range that will boost the actual capacity and integrating trained ANN in the conventional model to boost the yield capacity of tomatoes.

The characteristics metrics like the temperature, humidity, soil moisture and quantity of tomatoes it yields were checked. All these characterized data that were imbibed inside the model do not meet the threshold range; hence, an Artificial Neural Network (ANN) was trained.

Validation of the percentage improvement in the production capacity of tomato in a greenhouse with and without Model Predictive Controller were carried out and computed as below;

Conventional quantity of tomato produced in a greenhouse = 35 tons.

Model Predictive Controller (MPC) quantity of tomato produced in a greenhouse= 42.7 tons

The percentage improvement in quantity of tomato produced in a greenhouse when MPC was incorporated in the system was calculated as

$$\frac{\text{MPC quantity of tomato produced - Conventional quantity of tomato produced}}{\text{Conventional quantity of tomato produced}} \times \frac{100\%}{1}$$

The percentage improvement in quantity of tomato produced in a greenhouse when MPC was incorporated in the system =

$$\frac{42.7 \text{ tons} - 35 \text{ tons}}{35 \text{ tons.}} \times \frac{100\%}{1}$$

The percentage improvement in quantity of tomato produced in a greenhouse when MPC is incorporated in the system = 22%

IV. RESULT

The results obtained in this research are presented in the tables and figures below;

Table 1: Characterized Tomato Yield in Normal Weather Condition

Metric or parameter	**Normal Weather**
Temperature (^{O}F)	62^{0}F
Relative humidity (%)	75%
Soil moisture (%)	50%
Quantity(Tons)	30

Table 1 above depicted the characterized tomato yield in normal weather condition with respect to temperature, humidity, soil moisture and quantity**.** The characterized tomato yield in condition weather environment (Greenhouse) with respect to temperature, humidity, soil moisture and quantity is presented in table 2 below;

Table 2: Characterized tomato yield in Greenhouse

Metric or parameter	**Greenhouse**	**Acceptable Standard Range**
Temperature (^{O}F)	76^{0}F	(Standard 75^{0}F to 85^{0}F)
Relative humidity (%)	70%	(Standard 65% to 85%)
Soil moisture (%)	75%	(Standard 50% to 90%)
Quantity(Tons)	35	

The conventional model for production capacity of tomatoes in Greenhouse farm is presented in figure 1 below;

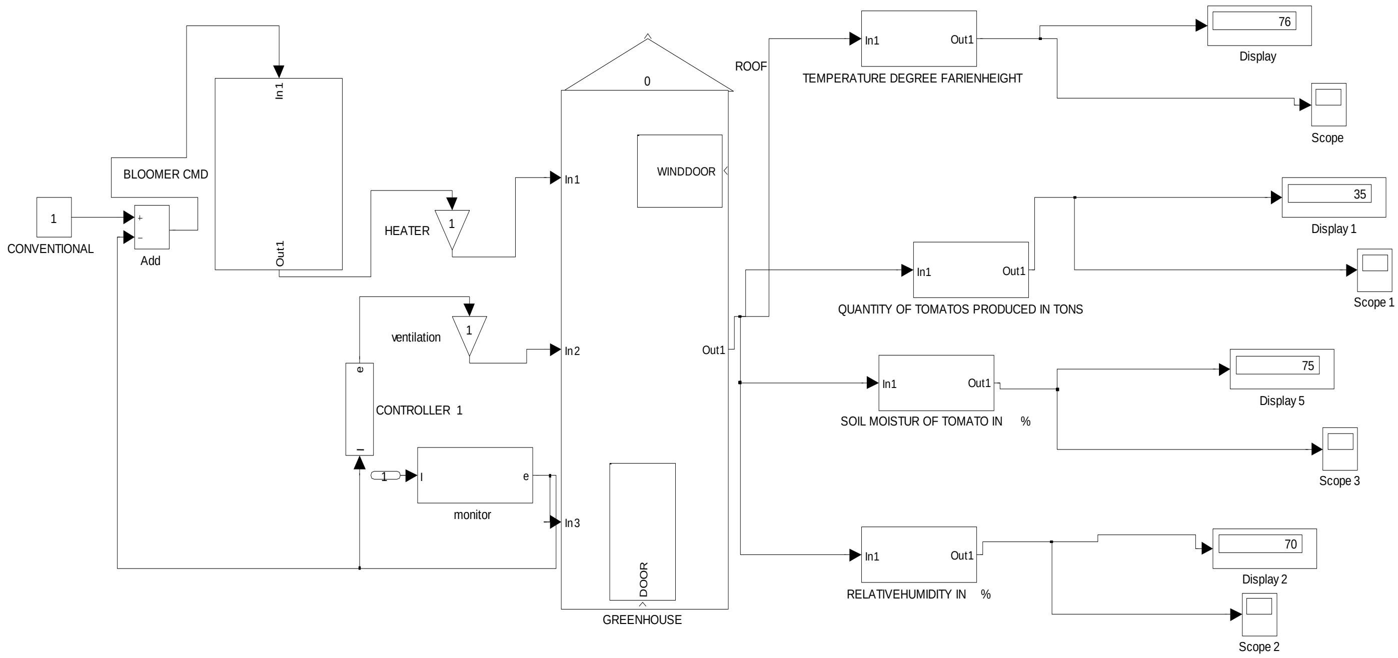

Figure 1: Conventional Model for Production Capacity of Tomato Yield in Greenhouse

The result of Conventional quantity of tomatoes produced in a Greenhouse (tons) is presented in table 3 and Figure 2 below;

Table 3: The result of Conventional quantity of tomatoes produced in a Greenhouse

Time (months)	**Conventional quantity of tomatoes produced in a Greenhouse (tons)**
1	20
2	30
3	33
4	35
10	35

The chart of conventional quantity of tomatoes produced in a Greenhouse (tons) is presented in figure 2 below;

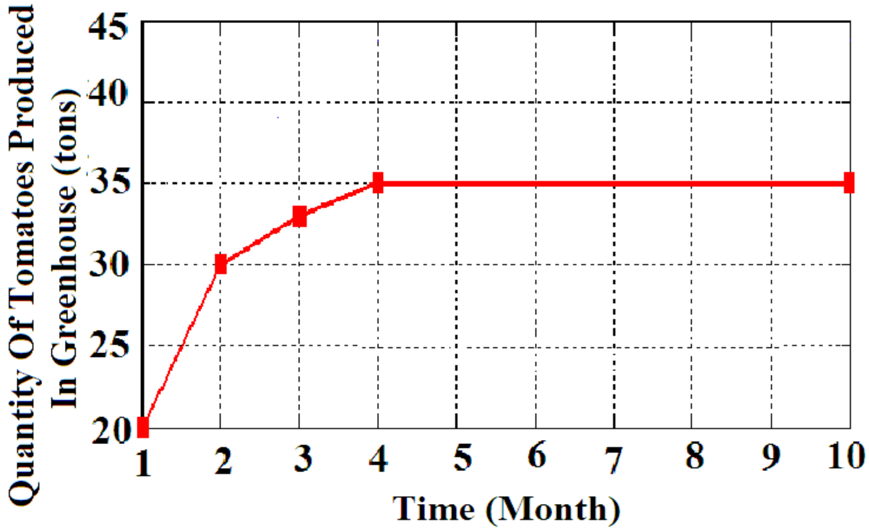

Figure 2: Conventional quantity of tomatoes produced in a Greenhouse

The result of MPC quantity of tomatoes produced in a Greenhouse (tons) is presented in table 4 and figure 3 below;

Table 4: MPC quantity of tomato produced in a greenhouse

Time (months)	**MPC quantity of tomatoes produced in a Greenhouse (tons)**
1	25
2	36
3	40
4	42.7
10	42.7

The chart of MPC quantity of tomato produced in a greenhouse is presented in figure 3 below;

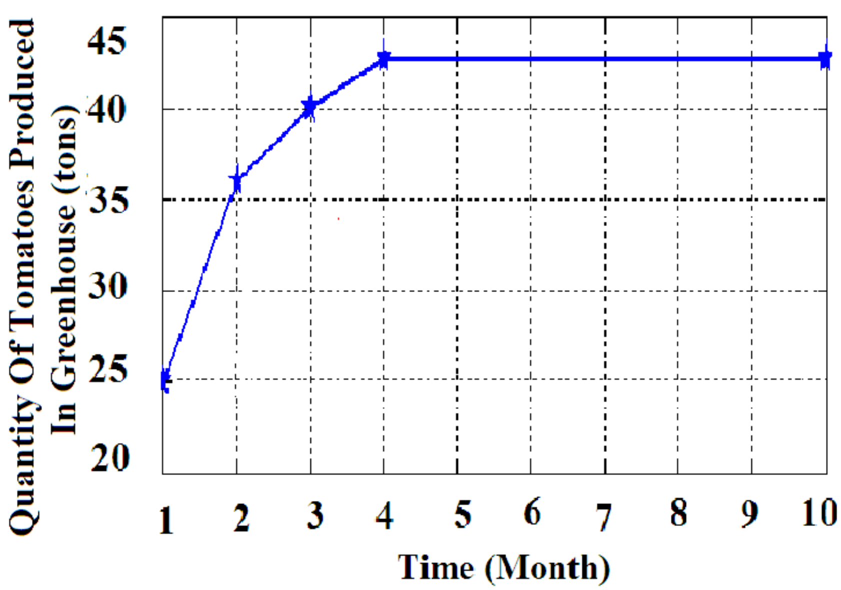

Figure 3: Chart of MPC quantity of tomatoes produced in a Greenhouse

The Comparison chart of Conventional and MPC quantity of tomato produced in a greenhouse is presented in figure 4 below;

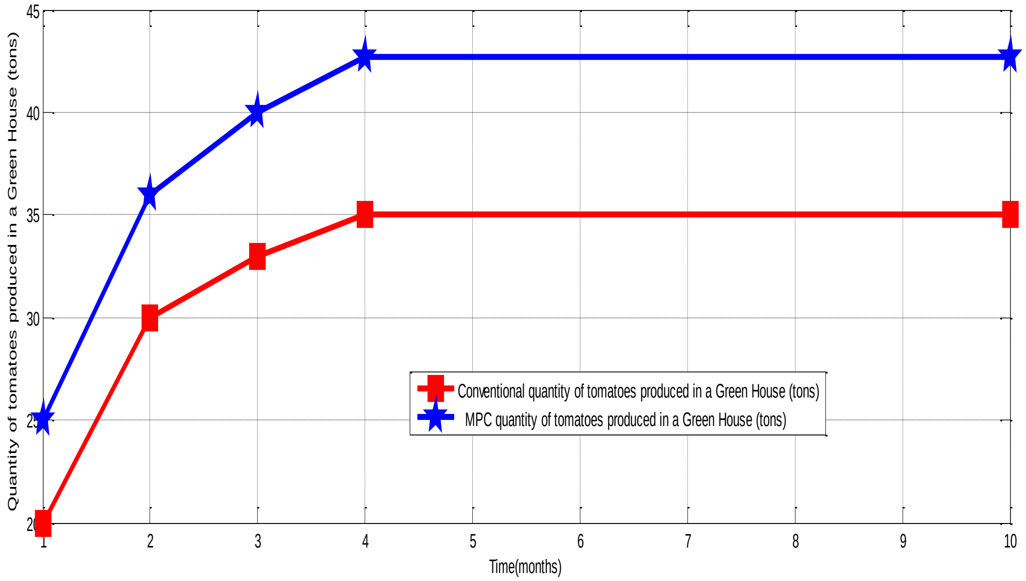

Figure 4: Comparison of Conventional and MPC quantity of tomato produced in a greenhouse

Trained ANN in a default tomato temperature, relative humidity and soil moisture to attain standard range that boosts its yielding capacity is presented in figure 5 below;

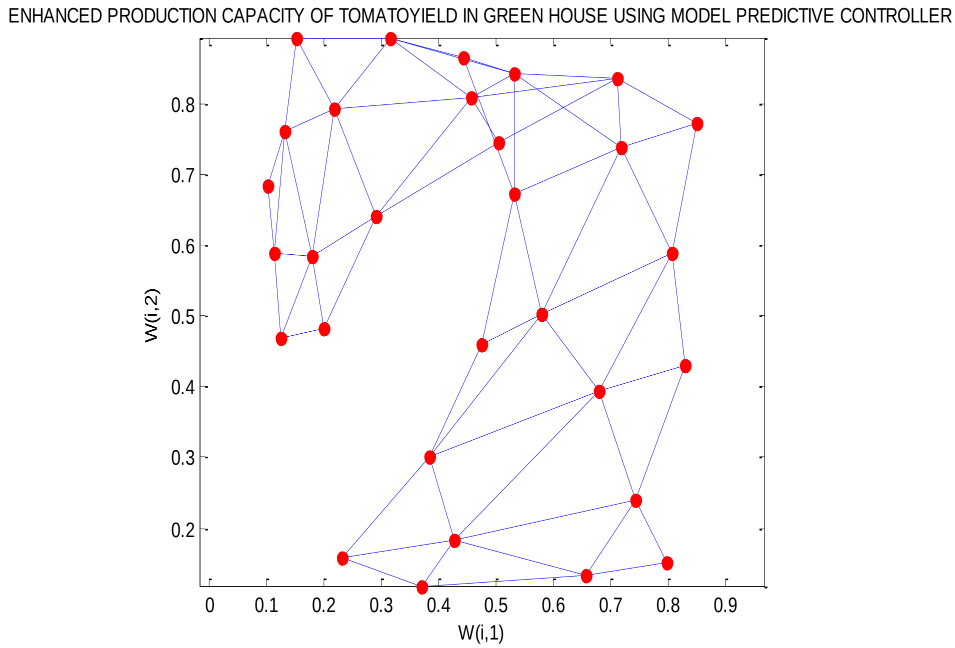

Figure 5: Trained Artificial Neural Network for Production Capacity of Tomato

Figure 5 shows a trained ANN in a default tomato temperature, relative humidity and soil moisture to attain standard range that will boost its yielding capacity. The resulting outcome is presented in figure 6 below;

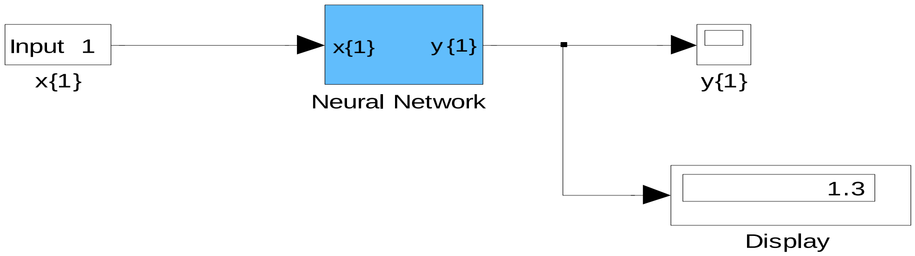

Figure 6: Result Obtained from the Trained ANN.

The trained ANN in a default tomato temperature, relative humidity and soil moisture from Figure 6 above, integrated into a Simulink model for Model Predictive Controller to attain standard range that will boost its yielding capacity is presented in figure 7 below;

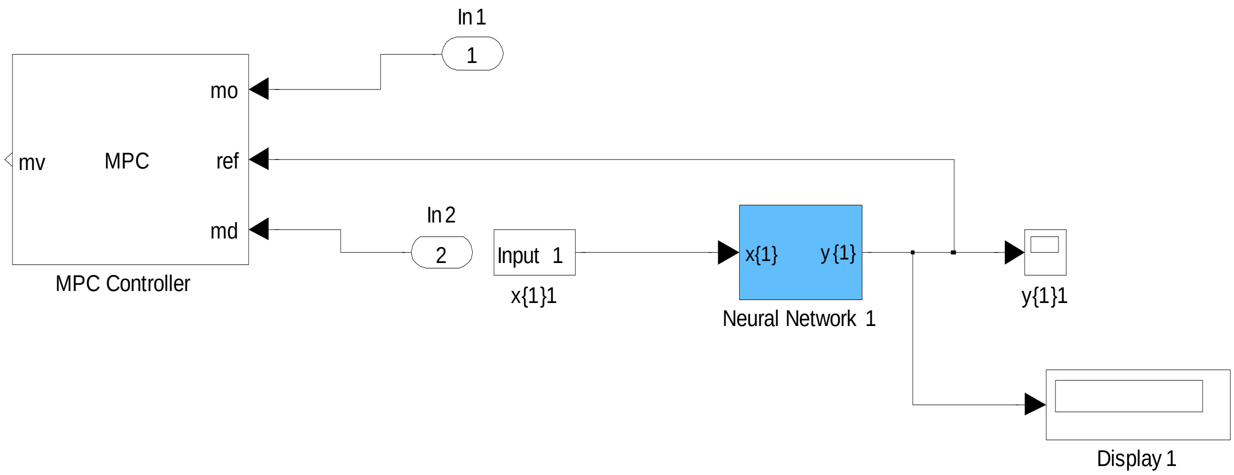

Figure 7: Integration of Trained ANN in a Model Predictive Controller

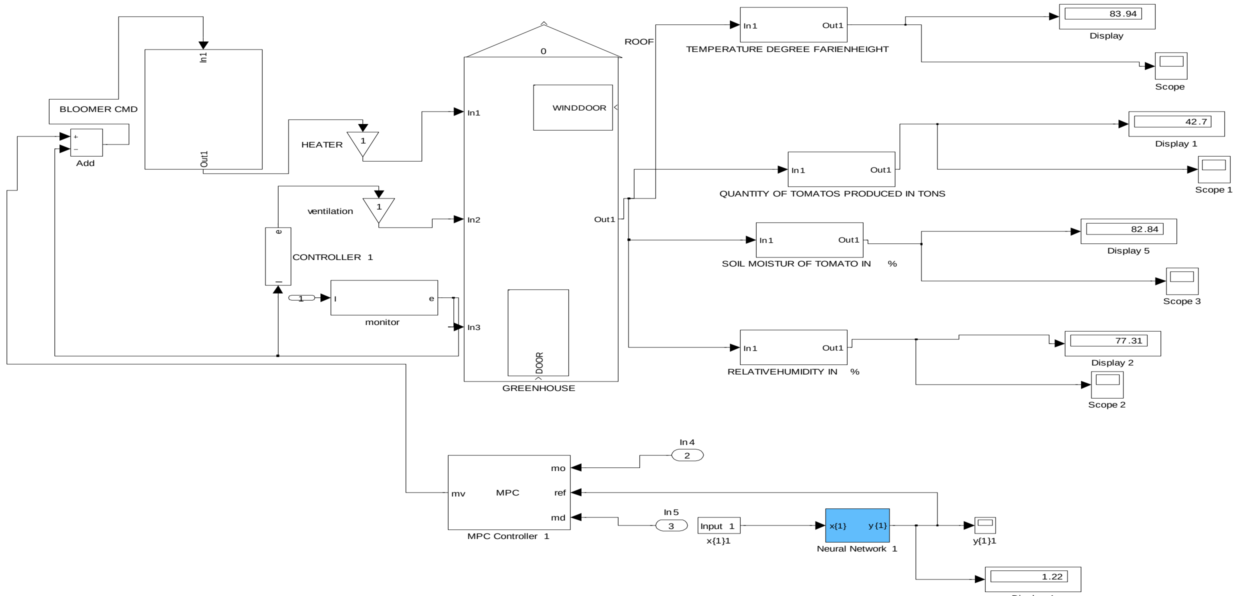

Figure 8: Integration of Trained ANN in the Conventional Model

V. DISCUSSIONS

The poor production of tomatoes in a greenhouse has arisen as a result of not having appropriate controlling mechanism that would control the soil relative, humidity, temperature and soil moisture for high yield of tomatoes. This was achieved by introducing an enhanced production capacity of tomatoes yield in greenhouse using Model Predictive Controller.

To achieve this, it was done in this procedure, characterizing and modeling tomato yield in normal weather condition with respect to temperature, humidity, soil moisture and quantity, training ANN in a default tomato temperature, relative humidity and soil moisture to attain standard range that will boost its yielding capacity, integrating the trained ANN in a default tomato temperature, relative humidity and soil moisture in a Simulink model for Model Predictive Controller to attain standard range that will boost its yielding capacity and integrating trained ANN in the conventional model to boost the yield capacity of tomatoes.

The quantity of tomatoes produced in a greenhouse using conventional model was 35 tons. On the other hand, when MPC controller was incorporated in the system it boosts the quantity of tomatoes to 42.7 tons. With these results obtained, it shows that the percentage improvement in the production of tomatoes in a greenhouse when MPC was integrated in the system was 22%.

Figure 7 shows the integration of trained ANN in a Model Predictive Controller in a Simulink model with respect to temperature, relative humidity and soil moisture to attain standard range that will boost its yielding capacity. Moreover, the trained ANN was also integrated in a conventional model in order to check the production capacity of the tomatoes. This was shown in Figure 8.

V. CONCLUSION

From the results obtained, the conventional quantity of tomatoes produced in a greenhouse was 35 tons. On the other hand, when MPC controller was incorporated in the system it boosts it to 42.7 tons. With these results obtained, it shows that the percentage improvement in the production of tomatoes in a greenhouse when MPC was integrated in the system was 22%.

It was thus concluded that Model Predictive Controller enhanced production capacity of tomatoes yield in the greenhouse.

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