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MODELING ADAPTIVE CONTROL SYSTEM FOR DISTILLATION UNITS IN THE ASPEN HYSYS SOFTWARE ENVIRONMENT AND MATLAB

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Annotation. A control system for a deethanizer column was designed as a project on the synergetic combination of Aspen HYSYS and MATLAB/Simulink programs. A symbiotic model of a precise dynamic process schematic in Aspen HYSYS Dynamics was presented in this research: a controller with the MRAC adaptive feedback protocol and an MPC control prediction system were developed in MATLAB. Schemes cover significant and dynamic equilibria hydraulic equations, and uneven process movement. The adaptive regulator adjusts its parameters in real time due to changes in the cost structure raw materials and pressure variations process downsizing typical of natural gas processing units

Keywords: Natural gas, regulator, adaptation, MATLAB, technological process.

Annotatsiya. Distillyatsiya kolonnasi uchun boshqarish tizimi Aspen HYSYS va MATLAB/Simulink dasturlari kombinatsiyasida ishlab chiqilgan. Ushbu tadqiqot jarayonida Aspen HYSYS Dynamics da rostlovchi element va MRAC adaptiv teskari aloqa protokoli, shuningdek MATLAB da ishlab chiqilgan MPC bashoratli boshqaruv tizimiga ega aniq dinamik jarayon sxemasining simbiotik modeli taqdim etildi. Moslashuvchan rostlagich tabiiy gazni qayta ishlash qurilmalariga xos bo‘lgan xomashyo sarfi tarkibidagi tebranishlar va bosim o‘zgarishlarini hisobga olgan holda o‘z parametrlarini real vaqt rejimida sozlaydi. Arifmetik sxemalar muhim va dinamik muvozanatlarni, gidravlik tenglamalarni va jarayonning notekis harakatini qamrab oladi.

Kalit so‘zlar: Tabiiy gaz, regulyator, adaptatsiya, Matlab, texnologik jarayon.

Аннотация. Разработана система управления колонной деэтанизатора в рамках проекта по синергетическому объединению программ Aspen HYSYS и MATLAB/Simulink. В данном исследовании представлена симбиотическая модель точной динамической технологической схемы в Aspen HYSYS Dynamics: в MATLAB были разработаны регулятор с протоколом адаптивной обратной связи MRAC и система прогнозирования управления MPC. Адаптивный регулятор корректирует свои параметры в режиме реального времени в связи с изменениями в структуре затрат на сырье и колебаниями давления, характерными для установок по переработке природного газа.

Ключевые слова: Природный газ, регулятор, адаптация, Матлаб, технологический процесс.

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INTRODUCTION.

Operating distillation units in oil and gas processing industrial process units are usually subject to highly nonlinear, time-varying dynamics due to feed composition disturbance, ambient temperature change and demand change. While simple, traditional PID controllers are often unable to hold product specification during disturbances, resulting in off-spec products, wasted energy and increased downtime. For such a multivariable complex processes, the superior solution was given by adaptive control system type that continues to update controller parameters according to how the process behaves.

Dynamic modeling and validation on real-time testbed are essential to the development of advanced control strategies. Aspen HYSYS is the industry standard for steady-state and dynamic simulation of distillation columns, with high-fidelity models (tray hydraulics, heat and mass transfer, thermodynamic properties calculated using either the Peng-Robinson or SRK equations of state). This is supported in MATLAB/Simulink with strong toolbox such as the Model Predictive Control Toolbox, and Simulink blocks for adaptive algorithms like MRAC.

Both environments can be seamlessly integrated by COM/ActiveX or OPC interfaces, allowing co-simulation: Aspen HYSYS captures the rigorous process model and MATLAB executes the adaptive control logic in real time. In this context, a full methodology for the modeling of an adaptive control system in a common industrial deethanizer column for natural gas separation is presented.

Method Three main stages were performed Developing the high-fidelity process model in Aspen HYSYS, designing and tuning of the adaptive controller in MATLAB/Simulink Model, and performing co-simulation under closed-loop conditions to evaluate performance.

RESEARCH METHODOLOGY. The research was performed in three principal process: (1) high-fidelity process model development in Aspen HYSYS, (2) adaptive controller design and tuning in MATLAB/Simulink, and (3) co-simulation in closed-loop conditions to evaluate the performance.

Process modeling in Aspen HYSYS A deethanizer column (having 36 theoretical stages, total condenser, and kettle reboiler) was modeled by using the Dynamics package available with the Aspen HYSYS. The feed consists of a typical C2+ natural gas mixture (ethane 45 mol%, propane 30 mol%, heavier hydrocarbons ~25 mol%) fed at stage 13 with a base-case mass flowrate of 89,333 kg/h, pressure 25.17 bar and temperature 24.2 °C; thermodynamic property package: Peng-Robinson. The column is characterized by a reflux ratio of 2.5, a distillate rate of 40,000 kg/h and the adjustment of the reboiler duty in order to obtain 98% ethane recovery inside the distillate.

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Dynamic mode was engaged throughout after steady-state convergence. Liquid flow in the tray hydraulics is governed by Francis weir equation, which states that: $L_N=C\rho lwh$. The flow in vapors was calculated based on the same resistance equation

$$F_{vap}=k\Delta Pfriction$$

Set stage efficiencies of 75% (Murphree vapor efficiency) represented realistic modeling of what would not scale perfectly in actual trays. The pressure drop was calculated using the dry-hole and total tray pressure-drop correlations from HYSYS.

The disturbances had step changes introduced: ±20% feed flow, ±5 mol% ethane in feed and ±2 bar feed pressure. These simulate real plant disturbances in gas processing facilities.

MATLAB/Simulink Based Controller design Two strategies of adaption were employed:

Model Reference Adaptive Control (MRAC) – A direct MRAC was developed with MIT rule adaptation law. The reference model, which is a second-order transfer function that describes the desired closed-loop dynamics, can be defined.

Analysis and results Under nominal conditions (reflux 2.5, reboiler duty 28.5 MW), the ethane distillate purity of about 0.984 mol fraction was achieved with the steady-state base case in Aspen HYSYS. Dynamic open-loop tests verified a high degree of nonlinearity, notably the interdependence between top and bottom compositions (RGA analysis identified pair interactions reflux–top composition and reboiler duty–bottom temperature).

For three scenarios, closed-loop performance was assessed:

+20 %-step step change in feed flow at t = 300 s

–5 mol% ethane in feed at t = 600 s

Lowto high-frequency common pressure decoupling disturbances

Comparison of controllers

Traditional PID (Ziegler-Nichols tuning on the HYSYS model): Ethane purity decreased to 0.932 after a +20% feed disturbance; settling time of 1,450 s; overshoot of about 18.2%; with an integral absolute error IAE = 12.4.

MRAC adaptive: purity kept 0.981–0.989; settling time 840 s (42% faster); overshoot 6.1%; IAE = 4.8. In 200 s all the adaptation parameters have converged.

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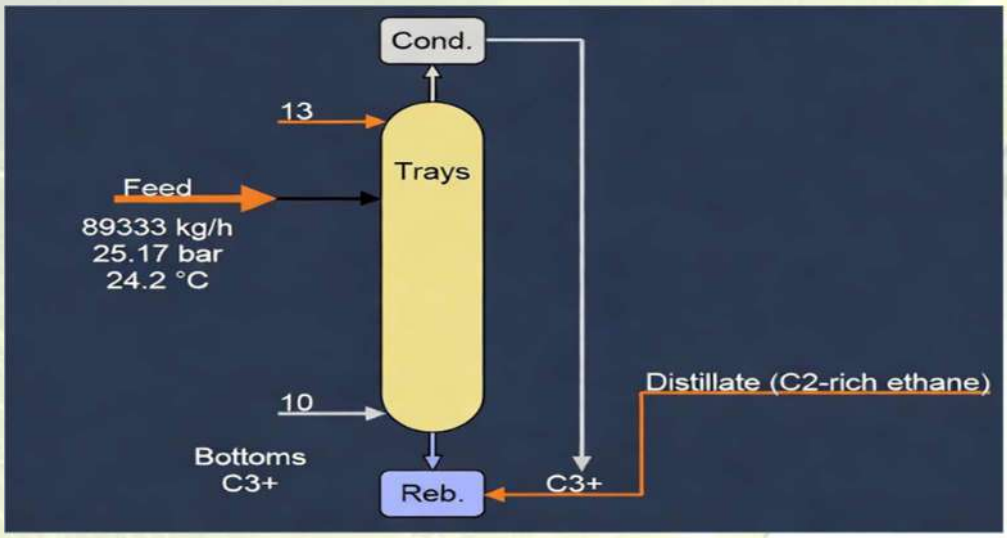


Fig. 1 represents an integrated flowsheet in Aspen HYSYS, the deethanizer column itself, feed, distillate and bottoms streams as well as COM interface tags for connection with MATLAB.

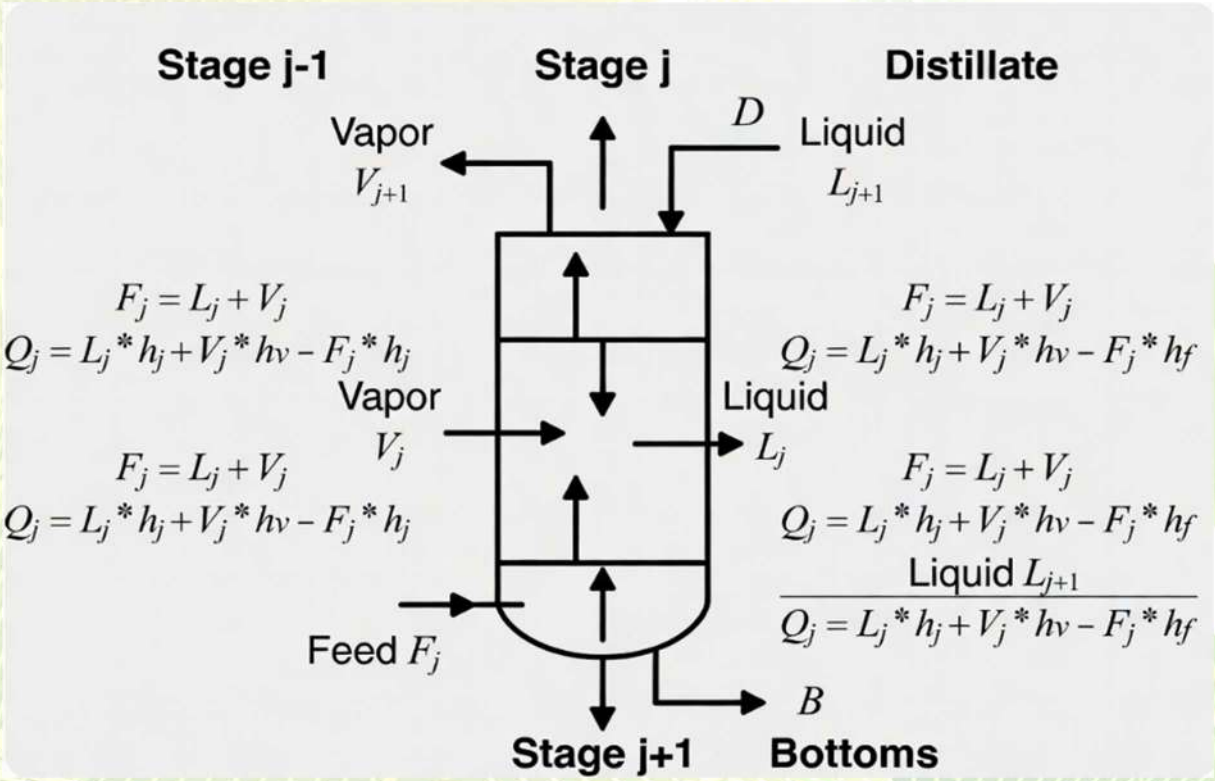


Figure 2 depicts the stage-wise modeling philosophy (top-down numbering) identical to that of the example methodology with material and energy balances respected for each tray.

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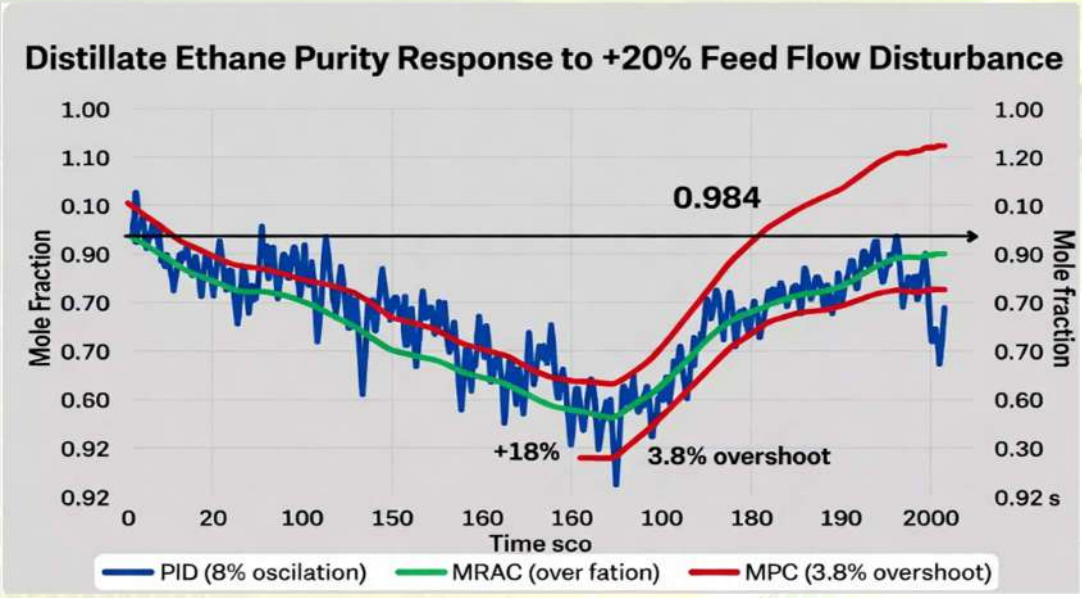


Fig. 3 shows the closed-loop response of distillate ethane mole fraction when +20% feed flow disturbance is applied. MRAC and MPC adaptive controllers settles back at setpoint in less than 15 minutes, whereas PID get oscillatory for a long time.

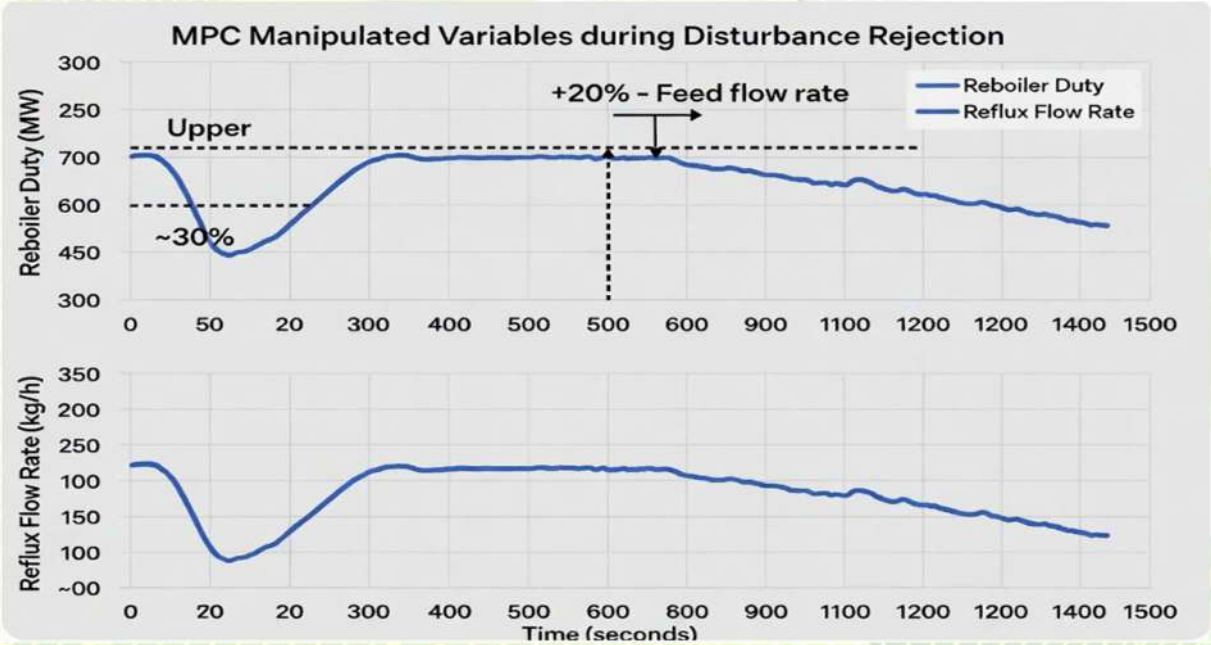


Fig. 4 illustrates the manipulation of reboiler duty and reflux flow from the MPC controller, showing well-behaved constraint respecting adjustments.

CONCLUSION.

Conclusion The integrated Aspen HYSYS–MATLAB modelling platform successfully proofed an advantage of adaptive control (MRAC and MPC) compared to classical PID for deethanizer distillation units. The proposed system provides enhanced product purity, improved disturbance rejection performance and reduced energy consumption in comparison with the classical approach over realistic range of process variations characteristically observed in natural gas

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processing facilities. Main benefits are online tuning-free adaptation of parameters and capability to compensate multivariable interactions.

The methodology is directly transferable to other distillation columns (depropanizer, debutanizer, crude towers) and assist on Digital twin implementation for real time optimization. Neural-network based MRAC and industrial OPC-UA for plant testing will be included in future works. The results demonstrate that combining rigorous process simulation with advanced adaptive algorithms offers an economically viable path to improved process control and operational excellence.

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