Preparation of Papers for IEEE Trans on Industrial Electronics (Apr. 2021)

First A. Author1, *Student Membership*, Second B. Author2, *Membership*, and Third C. Author3, *Membership*

***Abstract*—These instructions give you guidelines for preparing papers for IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS. Use this document as a template. The electronic file of your paper will be formatted further at IEEE. Paper titles should be written in uppercase and lowercase letters, not all uppercase. Avoid writing long formulas with subscripts in the title; short formulas that identify the elements are fine (e.g., "Nd-Fe-B"). Do not write "(Invited)" in the title. Write full names of authors in the author field. Define all symbols used in the abstract. Do not cite references in the abstract. Do not delete the blank line immediately above the abstract; it sets the footnote at the bottom of this column.**

***Index Terms*—Enter key words or phrases in alphabetical order, separated by commas. For a list of suggested keywords, send a blank e-mail to keywords@ieee.org or visit http://www.ieee.org/documents/taxonomy_v101.pdf.**

I. Introduction

THIS document is a template for authors. If you are reading a paper or PDF version of this document, please download the electronic file, TRANS-JOUR.zip, from the TIE Web site at http://www.ieee-ies.org/pubs/transactions-on-industrial-electronics so you can use it to prepare your manuscript.

After unzipping, choose Word or LATEX option. Open ALL_xx-TIE-xxxx.docx for Word or ALL_x-TIE-xxxx.tex for LATEX (highly recommended).

These types of manuscript are accepted in TIE:

II. System Description

The energy production landscape is gradually shifting from a centralized model towards more decentralized systems. This transformation is evident in the increased deployment and integration of renewable energy sources. Single wind turbine, and rooftop PV have are moving fast towards wind and solar farm. As result of this transition, an increasing numerous works focused on potential issues arising from a scattered production at different level. As an example in paper 1 the authors studies the return of investment of the design of distributed energy resources. Other studies focuses on how a distributed scenario could benefit the industry, or how policy maker could push for emerging markets for distribute resources. On the bottom level, the integration of grid-based inverters playing a pivotal role in designing a grid able to maintain a power quality and stability. In fact it is known that with the increasing amount of renewables, the grid is being more exposed to fluctation and stochasticty mainly driven by the weather forecast, requiring the energy storage and ancillary service includes managing voltage levels and frequency to prevent grid disturbances. Another part of the literature is focusing on scheduling and resource allocation under uncertainty. Methods like stochastic or robust optimization are now becoming more popular in order to minimize Value at Risk (VAr), under uncertain conditions.

A. Cloud Stuff

Power electronic converters (PECs) are ubiquitous and play a crucial role in renewable sources integration, serving as interconnection between the loads, energy storage systems and the grid. Numerous are the application of power converters for example in Electrical Vehicles (EVs) converting alternating current (AC) to direct current (DC) or in photovoltaic panels converting DC to AC, to match the grid frequency and voltage. Moreover, PECs are crucial in the operation of industrial electric drives to meet motors requirements in high power application. For instance, three-phase converters are commonly used in industrial settings due to their ability to handle high power requirements efficiently. It is clear that PECs are could play a major role in orchestrating loads, by leveraging their flexibility and adaptability. However, the aggregation of this flexibilities come with a price, especially in terms of data aggregation, computational resources, scalability and advances control techniques that are able to interact with cloud architecture, PLCs and APIs. (Read paper Musumeci)

Small summaries of paper analyzing could platform with gree transitions

[1] analyzes the challanges in communication, storages and computational capabilities in massive streams of data, while

Manuscript received Month xx, 2xxx; revised Month xx, xxxx; accepted Month x, xxxx. This work was supported in part by the xxx Department of xxx under Grant (sponsor and financial support acknowledgment goes here).

(Authors' names and affiliation) First A. Author1 and Second B. Author2 are with the xxx Department, University of xxx, City, Zip code, Country, on leave from the National Institute for xxx, City, Zip code, Country (e-mail: author@domain.com).

Third C. Author3 is with the National Institute of xxx, City, Zip code, Country (corresponding author to provide phone: xxx-xxx-xxxx; fax: xxx-xxx-xxxx; e-mail: author@ domain.gov).

[2] presents how IoT benefit the accurate forecasting and predictive mantainance ensuring high security levels. Paper [3] extensively review the literature on the application of IoT in energy sectors ans smart grids, by distinguishes the the transmission and distribution levels, where IoT can be applied to energy efficiency, aggregation of distributed generations and electric vehicles aggregation (V2G), from the demand side where IoT can be used for battery energy storage management and control to smart building control.

Wi-Fi, Bluetooth, ZigBee [4] LTE-4G and 5G networks [5]

III. System Identification

A. ARX Model

We have chosen to represent the system in *discrete time*,

$$y_t + a_1 y_{t-1} + \cdots + a_n y_{t-p} = b_1 u_{t-1} + \cdots + b_q u_{t-q} \tag{1}$$

$$\theta = \left[a_1, \ldots, a_p, b_1, \ldots, b_q\right]^T \tag{2}$$

$$\varphi(t) = \left[-y_{t-1} \cdots - y_{t-p}, u_{t-1} \cdots u_{t-q}\right]^T \tag{3}$$

$$y_t = \varphi_t^T \theta_t \quad \forall t \in (1, N) \tag{4}$$

For a given system we can collect inputs and outputs over a time interval t

$$Z^N = \left\{u(t_0), y(t_0), \cdots, u(N), y(n)\right\} \tag{5}$$

$$\hat{\theta} = \arg\min_x V_N(\theta) + \lambda(\theta - \theta^*)R(\theta - \theta^*) \tag{6}$$

The ARX(p, q) model is given by:

$$y_t = \sum_{i=1}^{p} \varphi_i y_{t-i} + \sum_{j=1}^{q} \beta_j x_{t-j} + \epsilon_t \tag{7}$$

B. Piecewise Linear function

Algorithm 1 Grouping Time Series Data by Bin Medians

Require: Time series data $y = \{y_1, y_2, \ldots, y_T\}$, excitation data $u = \{u_1, u_2, \ldots, u_T\}$, bin size n

Ensure: Grouped data by bin medians

1: Divide the time series y into bins of size n
2: **for** $i = 1$ to $\lceil \frac{T}{n} \rceil$ **do**
3: $\quad B_i \leftarrow \{y_{(i-1)n+1}, y_{(i-1)n+2}, \ldots, y_{\min(in,T)}\}$
4: $\quad$ Compute the median m_i of the bin B_i
5: **end for**
6: Group the data in y by their corresponding bin medians m_i

IV. Inflow Estimation

The considered wastewater pumping station, only the outflow and the height are measured, while the inflow is not measured or estimated. Therefore, in order to estimate the inflow of the tank, we implemented an observer by using the tank equation where the instantaneous rate of change of the height dh is proportional to the difference between the inflow and the outflow of the tank, scaled by the area of the tank, as pointed Eq.8.

$$h_t = h_0 + \frac{T_s}{A}(Q_{in,t} - Q_{out,t}) + v_t \tag{8}$$

where A, the cross-sectional area of the tank, T_s is the sampling time of the measurements, $Q_{in,t}$ and $Q_{out,t}$ are the measured inflow and outflow respectively, and v_t is the measurement noise.

By defining the the inflow $Q_{in,t}$ any time t, the hidden state the Eq.8, w_t the process noise, Q is the covariance of the process noise, and R is the measurement noise covariance.

$$Q_{in,t+1} = Q_{in,t} + w_t$$

The states can be estimated by means of the Kalman filter, at any given time t

Prediction Step:

$$\begin{aligned} \hat{Q}_{in,t+1|t} &= \hat{Q}_{in,t|t} \\ P_{t+1|t} &= P_{t|t} + Q \end{aligned}$$

where Q is the covariance of the process noise.

Update Step: Compute the Kalman Gain and update the estimate with the measurement:

$$\begin{aligned} \Delta h_{t+1} &= h_{t+1} - z_{h,t+1} \\ \Delta Q_{t+1} &= \hat{Q}_{in,t+1|t} - z_{Q_{out},t+1} \\ \hat{Q}_{in,t+1|t+1} &= \hat{Q}_{in,t+1|t} + K_{t+1}\left(\frac{A}{T_s}\Delta h_{t+1} - \Delta Q_{t+1}\right) \end{aligned}$$

V. Inflow Forecast

VI. Hierarchical Model Predictive Control

A. Higher-Level MPC

$$\min_{\zeta,} \sum_{t=1}^{T} \Gamma \left\| E \right\|_t^2 + \Lambda_t^T \sigma_t \tag{9a}$$

$$\text{s.t.} \qquad \forall \sigma_t \geq 0 \tag{9b}$$

$$\zeta_t = \sum_{j=1}^{3} \zeta_{t-1} \tag{9c}$$

$$Q_{in,t} \leq 0 \tag{9d}$$

$$h_{min} \leq h_t \leq h_{max} \tag{9e}$$

$$E_{min} \leq E_t \leq E_{max} \tag{9f}$$

B. Lower-Level MPC

$$\min_{\omega,E,P,Q_{\text{out}}} \sum_{k=1}^{h} \mathcal{Q}\left\|h_k - h_r\right\|^2 + \mathcal{R}\left\|\omega_k\right\|^2 + \Gamma\left\|E\right\|_k^2 + \Lambda_k^T\sigma_k \tag{10a}$$

$$\text{s.t.} \quad \forall\sigma_k \geq 0,\ l \geq 0 \tag{10b}$$

$$Q_{\text{out},k} = \sum_{j=1}^{3} Q_{out_{j,k-1}} \tag{10c}$$

$$E_k = \sum_{j=1}^{3} E_{k-l} \tag{10d}$$

$$P_k = \sum_{j=1}^{3} P_{k-l} \tag{10e}$$

$$Q_{in,k} = \tilde{Q}_{in,k-1} \tag{10f}$$

$$h_k = \frac{1}{A}\left(\tilde{Q}_{in,k} - Q_{out,k}\right) \tag{10g}$$

$$\omega_l - \sigma_\omega \leq \omega_k \leq \omega_u + \sigma_\omega \tag{10h}$$

$$P_l - \sigma_P \leq P_k \leq P_u + \sigma_P \tag{10i}$$

$$h_r - \sigma_{h_r} \leq h_k \leq h_l + \sigma_{h_r} \tag{10j}$$

C. References

This is the paper I am citing [6]

References

[1] L. Bagherzadeh, H. Shahinzadeh, H. Shayeghi, A. Dejamkhooy, R. Bayindir, and M. Iranpour, "Integration of cloud computing and iot (cloudiot) in smart grids: Benefits, challenges, and solutions," in *2020 international conference on computational intelligence for smart power system and sustainable energy (CISPSSE)*, pp. 1–8. IEEE, 2020.

[2] H. Shahinzadeh, J. Moradi, G. B. Gharehpetian, S. H. Fathi, and M. Abedi, "Green power island, a blue battery concept for energy management of high penetration of renewable energy sources with techno-economic and environmental considerations," in *2018 Smart Grid Conference (SGC)*, pp. 1–9. IEEE, 2018.

[3] N. Hossein Motlagh, M. Mohammadrezaei, J. Hunt, and B. Zakeri, "Internet of things (iot) and the energy sector," *Energies*, vol. 13, no. 2, p. 494, 2020.

[4] G. Karunarathne, K. Kulawansa, and M. Firdhous, "Wireless communication technologies in internet of things: A critical evaluation," in *2018 International conference on intelligent and innovative computing applications (ICONIC)*, pp. 1–5. IEEE, 2018.

[5] S. Li, L. Da Xu, and S. Zhao, "5g internet of things: A survey," *Journal of Industrial Information Integration*, vol. 10, pp. 1–9, 2018.

[6] A. Quattrociocchi, R. K. Subroto, W. M. Oppedijk, and T. Dragičević, "Energy efficiency optimization of a wastewater pumping station through iot and ai: A real-world application of digital twins," in *IECON 2023-49th Annual Conference of the IEEE Industrial Electronics Society*, pp. 1–6. IEEE, 2023.