Power system load forecasting employing alike day scheme upgraded fuzzy logic controller

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***Abstract*:** An exact power system load forecasting (PSLF) tool is a compulsory part of the electricity industry for profit maximization, energy conservation and environmental fortification by limiting energy resources' combustion. This investigation suggests an alike day scheme (ADS) upgraded the Sugeno fuzzy logic controller (FLC) model for exact PSLF. A new ADS is projected here to improve the FLC's forecasting ability by appraising quality training data under irregular load conditions. In the power system, the consumer behaviors that eventually govern the electric power system's demand are highly opinionated by thermal inertia, triggered by many climatic factors. So, the exactness of a PSLF model is highly dependent on the incorporated climatic factors. Therefore, in the proposed model, the new ADS considers various climatic factors while evaluating the training data. The research is being undertaken in Assam, a Northeastern state of India, and the proposed model is being used for the week ahead of the power load forecast. Compared to traditional FLC without ADS, the efficiency of the projected model is extremely very well. The experimental annotations authorize the dominion of the proposed model over conventional FLC.

***Keywords*: Power system load forecasting, Alike day scheme, Sugeno Fuzzy logic controller, Climatic factor**

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I. INTRODUCTION

In modern-day restructured power systems, the accuracy in power system load forecasting (PSLF) is an obligatory concern for operation, planning, control, maintenance, and sustainable development [1–4]. Moreover, it is an obligatory operation to ensure sustainable solutions for present-day electric power systems. Considering the PSLF methodology's tremendous importance in mind, various new, effective, efficient and robust PSLF model. The researcher has to review that finding out such methodology has numerous modern tactic in this power system background, reliable, powerful and robust PSLF models over the last decades. The various existing of these methods are Support vector machine [1–3], artificial neural networks [5], GEP [6], the fuzzy logic controller [7,8], ARMA [9], ARIMA [10], Kalman filter [11]. Amongst these existed approaches, the fuzzy logic controller (FLC) is set as one of the most accurate and reliable in the field of PSLF [7]. Hence, here the study going on an FLC to conduct an exact prediction of PSLF. The accuracy in an FLC based forecaster engine is also highly influenced by the quality of training data. The most conventional way of evaluating quality training data utilizes very recent data to stay in the required load demand trend [7,12]. When studied out on literature survey and in an experiment, it was suggested that the load demands are always fluctuating in nature and depend on thermal comport, which mainly depends on environmental climate change. If the climatic condition of the very recent day is not similar as the forecast day, then conventional way of evaluating the training data may mislead the PSLF system. The whole PSLF system will then train on the load data dissimilar to the forecast day load data. Therefore, to attain a good forecasting accuracy level on such irregular load conditions, this study proposes a new alike day scheme (ADS) to evaluate the quality training data. Moreover, these ADS will also help to integrate the climatic factors in the PSLF methodologies. The PSLF is divided into four groups according to the forecasting duration[8,13].

- Load forecasting of the very short-term power system: operates for a few hours.
- Load forecasting of the very short-term power system: operates for one week.

- Load forecasting of the mid-term power system: operates on four weeks.
- Load forecasting of the long-term power system: operates on a few months.

All four groups of forecasted duration have different functions in PSLF, such as very short terms are responsible for basic operations of the power system. Similarly, both midterm and long term forecasted duration to estimate the power system's planning or well operation [4]. The research is being undertaken in Assam, a North-eastern state of India, and the proposed model here is being used for conducting a week ahead of the power load forecast, and the proposed ADS upgraded FLC based PSLF model has engaged for some week ahead PSLF or short term PSLF. However, FLC based PSLF approach is successfully conducted in two cases studied in two different seasons. Where the performance study will see as well as such model compare with a new methodology of ADS.

The other left portion of this paper demonstrates as follows: we discuss the suggested ADS in Section 2; the architecture of the proposed PSLF model is described in Section 3. The FLC execution is clarifying in Section 4. In Section 5, case studies with forecasting results are shown. The conclusions are finally drawn in section 6.

II. ALIKE DAY SCHEME

The new Alike Day Scheme (ADS) is responsible for assessing good quality training data for the FLC. The temperature variables in the PSLF process are also combined. In this analysis, temperature and wind speed are considered climate factors, as both climate factors in the study area are considered influential[2,3]. Any related days are measured from previous historical days, according to these ADS. Similar days are the day, the atmospheric patterns of which are very similar to the daily forecast. A new Euclidian standard is based on the quest for identical days here (EN). The lower the EN's value, the more comparable the alike day is to the expected forecasted day. However, the expression of the EN here is:

$$EN = \sqrt{(T_t - T_t^p)^2 - (V_t - V_t^p)^2} \qquad (1)$$

Here, T_t is the present temperature value is taken into account, and T_t^p , as the latest historical value, V_t is considered to be the wind speed value of the current day, and the recent historical wind speed value. In order to obtained best solution through FLC, the consider EN value shown in Eq. (1). So, far for each forecasted days may be calculated through an ADS methodology. However, alike days are picked up from the past historical days. All these past forecasted load demands are easily getting from SLDC, Assam. Here, the ADS methodology is responsible carry a unit for data processing where all the previous data storing of climatic factors such as (wind speed and temperature) and the related value of the load demand are present as this unit has obtained the forecast value of climate factors, which is the key vital role in PSLF approach, for a particular date. This unit should assess the alike days with the new EN aid as defined in Eq. (1). So it is recommended that the FLC-based ADS approach trained the data from those alike days along with last two months before and after a given forecast day was selected as the boundary of the forecast day's search.

III. REPRENTATION OF THE SUGGESTED NEW PSLF MODEL

Fuzzy logic controller (FLC) is a popular mechanism in the PSLF probing field, because of its simplicity and accuracy. However, FLC's function is required for a specific input variable; the fuzzy system can map a specific output variable. In this work, the Sugeno FLC is utilized. The architecture of the PSLF model proposed is depicted in Fig. 1. However, the different input and output variations for the FLC are clearly seen in Fig. 1. The inputs to the FLC are (i) electric power consumption (MW), (ii) temperature forecast in (0C), (iii) wind speed forecast in (km/s), (iv) binary input (0 or 1) to decides the day type (if it is a holiday or working day). This given input information's are accessed through the FLC based proposed ADS approach. However, this FLC-based model's output will forecast hourly to show the information, which continuously estimates a week (168 hr). All these information were taken from the SLDC, Guwahati, Assam, India, for this work. The following section explaines the application of this new model.

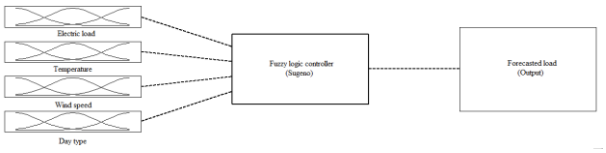

Fig. 1. The proposed PSLF model.

IV. THE DETAILS OF FLC EXECUTION METHODOLOGY

This topology uses FLC based alike day like scheme load forecasted, and it has been studying in three steps of deployment. However, at the very first step, the input and output quantities are assigned to the different fuzzy values. Both inputs and outputs are exchanged by assigning certain membership functions in such fuzzy sets, as seen in Fig. 2-Fig. 6. The topology is based on ADS, is dependent on electrical load demand (in kW), and prefers to be the input parameter, and then all input parameters are split into different five membership functions. These are weak demand for the load (EL), low demand for the load (L), normal demand for the load (N), high demand for the load (H), an extreme requirement for the load (EH). The allocation of fuzzy rules in the forecasting framework is the second stage of FLC execution. However, this methodology's peculiarity is that strongly nonlinear relationship between the input parameter and the concerned controller's output parameter. Here, 36 rules for performing the required PSLF are applying in this work. The execution of the fuzzy inference is the last step of FLC implementation. It is a method for finding out very easily on the output parameter which may require mapping for the considered combinations of input variables. This mapping parameter also may drive the outcomes on certain input variables. So in the end, the defuzzified output values are

derived from this method, and hence in this way, such FLC is implementing in this new methodology.

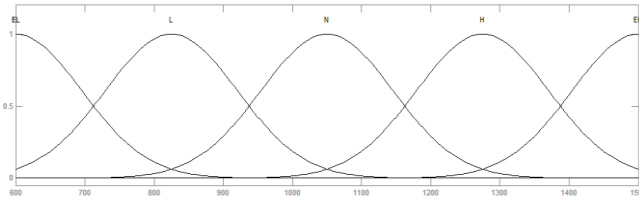

Fig. 2. Allocated membership function for the input load demand (MW).

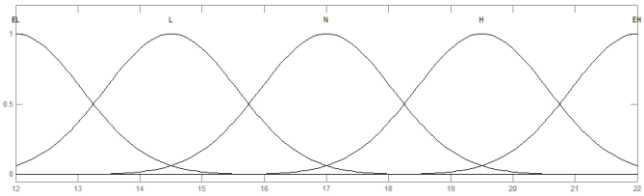

Fig. 3. Allocated membership function for temperature data (^{0}C).

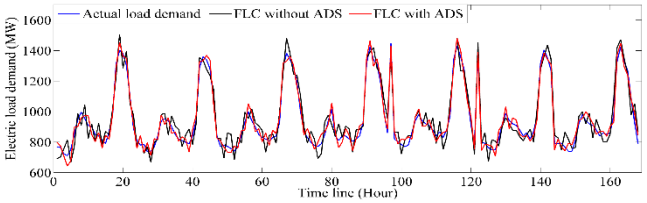

Fig. 7. Forecasting performance in the first case.

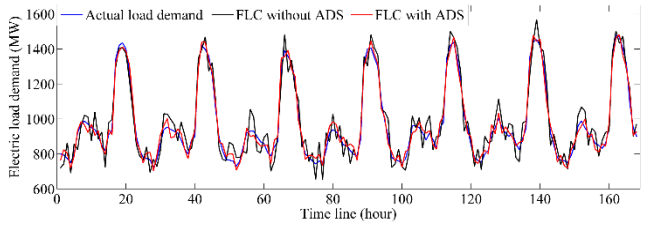

Fig. 8. Forecasting performance in the second case.

TABLE I. FORECASTING RESULTS OF BOTH THE MODELS FOR THE CASES

Cases	FLC without ADS				FLC with ADS				MAPE difference (i-ii)
	Maximum load deviation (in MW)	Minimum load deviation (in MW)	Average load deviation (in MW)	MAPE (%) i	Maximum load deviation (in MW)	Minimum load deviation (in MW)	Average load deviation (in MW)	MAPE (%) ii	
1	121.57	-2.99	56.57	6.17	-73.01	1.78	34.24	3.76	**2.41**
2	125.88	-3.09	58.58	6.29	61.65	-2.08	29.58	3.14	**3.15**

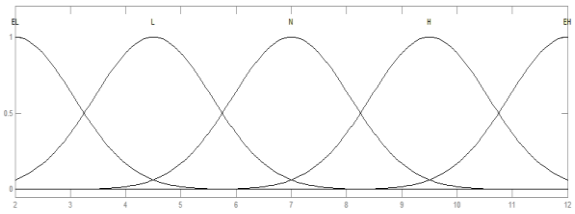

Fig. 4. Allocated membership function for wind speed (km/s)

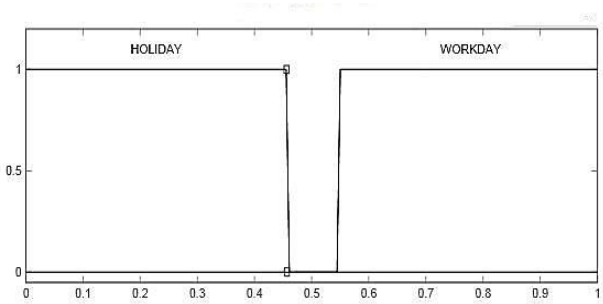

Fig. 5. Allocated membership function for day type.

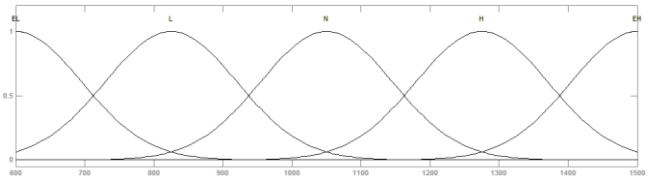

Fig. 6. Allocated membership function for the output load demand (MW).

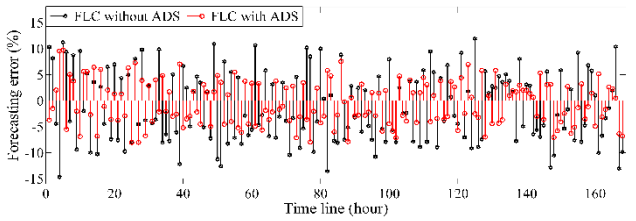

Fig. 9. Generated forecasting error in the discrete points along the timeline in the first case.

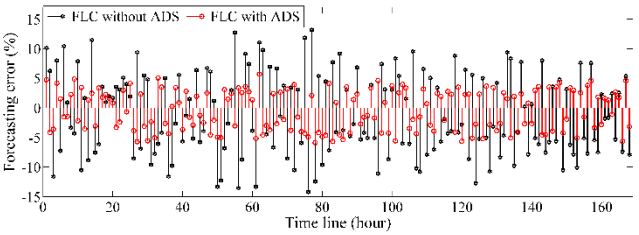

Fig. 10. Generated forecasting error in the discrete points along the timeline in the second case.

The generated forecasting error in the discrete points along the timeline in the first and the second cases is presented in Fig.9 and Fig.10, respectively. It is obvious that, in both the case studies, the proposed model shows lower forecasting error in almost every discrete point along with the timelines. Henceforth, it can be claimed that the proposed FLC with ADS model is more consistent forecaster than the conventional FLC without ADS model.

At the same time, it comes to the consideration of forecasting accuracy. In Table I, the forecasting results is shown. In the proposed FLC with ADS model, the generated maximum, minimum and average load deviancies (among the discrete points along the timeline) in both the cases are significantly low compared to the conventional FLC without ADS model. Apart from this, the proposed FLC's inclusive MAPE with ADS model is also considerably less compared to the conventional FLC without ADS model. The models' MAPE difference clearly demonstrates that the proposed model in all aspects outplays the conventional FLC without ADS model.

V CONCLUSIONS

As successfully study on ADS based PSLF methodology carried on different climatic condition with obtaining proper precision. However, the new MAPE methodology can enhance the quality of the training data and improve the system performance, which may be demonstrated in the following Fig. 7 to Fig.10, where all key parameter mainly focuses on environmental factor. The major contributions of this particular work can be highlighted as (i) An ADS methodology is considered for evaluating upcoming quality training data using the FLC, (ii) the ADS upgraded FLC is offered to incorporate the different climatic factors in the forecasting process, (iii) PSLF is carried out the week ahead, and performance is compared and evaluated for both enhance the system reliability as well as analyzed successfully. Moreover, all newly obtained results are correlated with the conventional FLC based model. This research is being conducted in Assam, India's northeastern province, and the proposed model is estimated for the week ahead PSLF. This new methodology defined model is compared to the conventional FLC without ADS methodology, and two case studies are carried out in two separate seasons of a year (e.g. considering in spring and another case study on winter). In both times, almost the conventional FLC was contained in the MAPE of the proposed model without ADS method. However, such an approach will provide minimum, and maximum power demand based on the discrete timeline demonstrated. Hence, the proposed PSLF model is a credible alternative model in the branch of the efficient PSLF model. In Assam, only 37 % of the families can use electricity as of 2016, and the state is still not doing good enough to meet its daily peak power demand [14, 15]. Therefore, for such a power scarcity state, an exact PSLF model is an obligatory toolbox for the policymakers to fix the future corrective course of action. Furthermore, the proposed PSLF model's greater accuracy can help any power generating stations meet the demand precisely without any overproduction or under production.

Hence, the proposed PSLF model can provide financial benefits to the electricity industry and be used for energy conservation and environmental fortification by limiting the power generating stations' combustion of energy resources (coal or gas).

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