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Burak Omer Saracoglu

*Abstract-* There is only one place, that our species live on today, Earth. Climate change is one of the threats for our planet. Main cause of the climate change is the human activities (excluding orbital variations, Sun's cosmic rays, volcanism, plate tectonics, etc.). One of the human activities, that causes the climate change, is the electricity consumption and generation. These activities has to be performed in a non-polluted way. There are some grid recommendations in this respect based on 100% renewable power generation, instead of as usual grid applications. One of them is the Global Grid. It is a worldwide 100% renewable power grid. Some Global Grid design research studies have been going on for a while. The Global Grid design should be presented very well by some strategic and long term plans. These plans should include annual peak power load (peak demand or load) (GW) forecasting of the Global Grid. This research is probably the first study in this respect.

*Keywords: global grid, peak load, fuzzy inference system, mamdani, prediction.*

*GJRE-J Classification: FOR Code: 091599*

COMPARATIVESTUDYONEXPERIMENTALTYPE1INTERVALGENERALTYPE2MAMDANIFISFORG2P3S

*Strictly as per the compliance and regulations of:*

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Burak Omer Saracoglu

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*Keywords: global grid, peak load, fuzzy inference system, mamdani, prediction.*

## I. Introduction

There are several grid types in the research, development, demonstration, and deployment (RD3) stages. Some RD3 engineers work on smart grids (see United States and European Union: [1, 2]). Some RD3 engineers work on Super grids and Global Grid (see [3]). In the smart grids, there are two way flow/communication networks. Electricity flows in one direction and information flows in opposite direction [4]. In the Supergrids and the Global Grid, there is only one way flow network. Only electricity flows in one direction like usual grids (business as usual). These conventional like grids work on the principles of bulk generation and storage [5]. This study considers that the Global Grid can be more effective and efficient in climate change actions. Two important main issues during development of the Global Grid are defined as human related issues (politics and its relations with wars, conflicts, ambitions, egos, etc.) and technical issues (electricity transmission, etc.). The first one can be solved by a revolution in human/people minds (no politics, no wars, no conflicts, no ambitions, no egos, etc.). A fair healthy living world can be designed, organized and managed by international organizations (properly modeled united nations: representation capability of each human being well). The most difficult technical issue is seemed power transmission (important RD3 direction) in the technical issues part. Wireless electricity transmission technology will technically and economically be possible for indoor and outdoor applications and usage in mid to long terms (idea supported by correspondence and literature) (see [6, 7, 8, 9] ). For instance, in outdoor applications, power transmission will be performed by wireless systems instead of transmission and distributions lines, or electric vehicles will be charged without any cables (any time or stationary charging). In indoor applications, home appliances will work without any cables. Hence, this research study focuses on the Global Grid main topic on way of taking some climate change actions (see [10,11] for crucial signs climate change).

Modeling and designing RD3 works/activities of the Global Grid (worldwide 100% renewable energy power grid) have to be finalized in a detailed manner.

One of the modeling tasks is forecasting/ prediction/projection of peak power load demand. There are several forecasting time horizons. The most common classification has four time horizons: immediate (less than 1 month), short-run (l–3 months), medium-term (3 months–2 years), long-run (2 years or more) [12,13,14]. In power grid documents, three time horizons are mainly observed as short (up to a week a head), medium (up to 10 years ahead) and long (50 years ahead) [15,16]. This research study is an extreme research study, that assumes the long range forecasting time horizon of the Global Grid as 100 years ahead.

Hence, annual peak power load/demand (GW) is taken into account in this 100 years prediction period. Models and predictions of these models on historical data can be used in future research studies and in

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strategic development and expansion plans of the Global Grid.

Section 2 presents literature review. The first experimental core type 1 and interval type 2 Mamdani Global Grid power load forecasting fuzzy inference systems (fuzzy control system, fuzzy rule base system, fuzzy expert system: FIS) on the JuzzyOnline V2.0 (http://ritweb.cloudapp.net:8080/JuzzyOnline/juzzy), and their first experimental comparative analysis are presented in Section 3. Adjusted models based on core models are also presented and compared amongst each other in Section 3. Conclusions and future research are presented in Section 4.

## II. Literature Review

Review activity was performed from 11/06/2015 to 01/07/2015 (20 days period). Search terms were found from previous studies, that were read before this research. Some key search terms were "fuzzy logic inference system" and "electricity", "fuzzy logic inference system" and "forecast", "fuzzy logic inference system" and "demand", "fuzzy rule system" and "electricity", "fuzzy rule system" and "forecast", "fuzzy rule system" and "demand". Total search hit number was 38727, that included all websites and documents (duplications etc. included). Journal papers, conference papers, and books were reviewed. Three academic publications' database websites contained majority of documents. These websites were ACM Digital Library [17], Google Scholar [18], and Springer [19]. Other websites didn't help to increase number of documents in research folder in this subject (ASCE Online Research Library [20], American Society of Mechanical Engineers [21], Cambridge Journals Online [22], Directory of Open Access Journals [23], Emerald Insight [24], Hindawi Publishing Corporation [25], Inderscience Publishers [26], Journal of Industrial Engineering and Management [27], Science Direct [28], Taylor & Francis Online/Journals [29], Wiley-Blackwell/Wiley Online Library [30], World Scientific Publishing [31]).

According to this review activity, there were four main time horizon groups found in literature (very short (e.g.[32]), short (e.g.[33]), medium (e.g.[34]), long (e.g.[35])). One of the studies in long term forecasting was by Al-zahra et.al. (2015) [36]. Monthly consumption in Basra, which characterized as nonlinear over time, was modeled by an Auto-Regressive Integrated Moving Average (ARIMA), an artificial neural network (ANN), and an adaptive neuro-fuzzy inference system (ANFIS) models. Mean absolute errors (MAE) were calculated as 0,31604 (Box-Jenkins ARIMA), 0,301 (ANN), and 0,2491 (ANFIS) [36]. Northern-Iraq's power load was studied by Demir (2014) [37]. Mean absolute percentage errors (MAPE) were 5,7% (Winters' additive) and 5,4% (seasonal ARIMA: SARIMA). Taiwanese load predictions were studied with a support vector regression (SVR) by Hong (2009) [38]. Findings showed that MAPE ranged between 1,29% and 2,45%.

During this review period, it was clearly understood that peak power load prediction topic was studied in different parts of the world by several researchers, however long term peak power load forecasting of the Global Grid Concept had not been studied until 01/07/2015. This research study was the first step in this new topic.

## III. Experimental Core and Adjusted Type 1 & Interval Type 2 Mamdani Fis Models for G²P³s

Fuzzy inference system's design approach has several important issues as inputs, outputs, membership functions, and rules identifications, inference type and defuzzification method selections [see 39,40,41]. Structure of a fuzzy rule base system is generally presented in literature as shown in "Fig. 1".

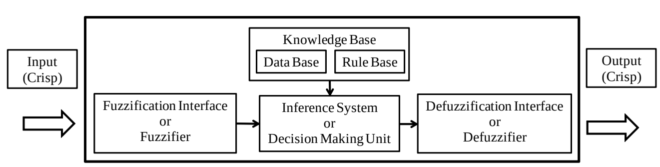
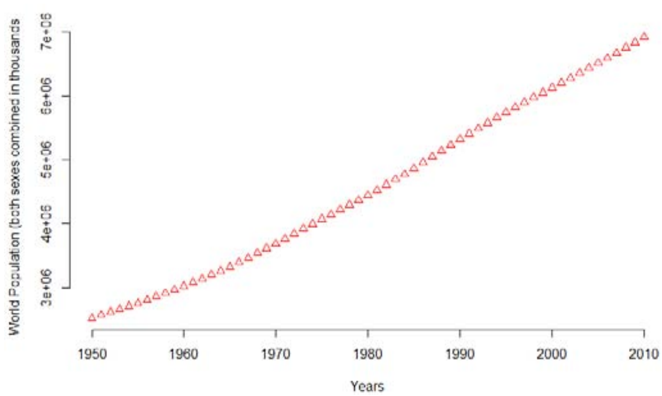



*Figure 1:* Fuzzy rule base systems (drawn based on [39], [42], [43])

Readers should here visit some important publications for FIS modeling and Juzzy Online for better perception of this research (see a few as [44-54]). Fuzzy inference systems in this research are founded on fuzzy logic principles and Mamdani fuzzy inference. Fuzzy set theory deals with un sharpness of human judgments. It was introduced by Lotfi A. Zadeh in 1965 [44]. Mamdani fuzzy inference was introduced by Ebrahim H. (Abe) Mamdani in 1974 based on Zadeh's fuzzy theory [45]. After 10 years from the first presentation of fuzzy set theory, Dr. Zadeh defined type-2 fuzzy sets in 1975 [46]. Afterwards, several academics and researchers contributed in this field. One of them is Dr. Yaochu Jin. His explanation on design of FIS philosophy is very easy to understand and important: "the most important thing is that the designed fuzzy system is theoretically able to realize the desired functional mapping. Therefore, the approximation capability of the fuzzy systems is of great concern.", "Furthermore, it has also been shown that various types of commonly used membership functions satisfy the conditions for the fuzzy systems to be universal approximators. By universal approximators, we mean that a fuzzy system can approximate any continuous functions on a compact set to an arbitrary degree of accuracy." [47]. This explanation and approach seriously guides this research study. Researchers underline that type-2 fuzzy logic sets and systems are more capable of handling uncertainties, than type-1 fuzzy sets and systems do [48, 49]. According to this judgment, two core models based on type 1 and interval type 2 (second model is related with first model) are built and compared in this study. Furthermore, it is mentioned by several academics that Mamdani's fuzzy rule based systems can handle human judgments better amongst other fuzzy inference systems (see [50,51]). Therefore, Mamdani's fuzzy rule based system is preferred instead of others (e.g. Sugeno). This research study is built on the JuzzyOnline V2.0 under these basic principles. It is a Java based online toolkit developed by Christian Wagner, Mathieu Pierfitte, and Amandine Pailloux [52,53,54].

Comparative analysis is mainly performed on two core experimental models on JuzzyOnline V2.0. These core models are type 1 and interval type 2 Mamdani FIS. Simple and easy experimental models are built in this early RD3 stage. Trial and error approach is followed during this research. There are two experimental inputs (world population, global annual temperature anomalies) and one experimental output (annual peak power demand) as such:

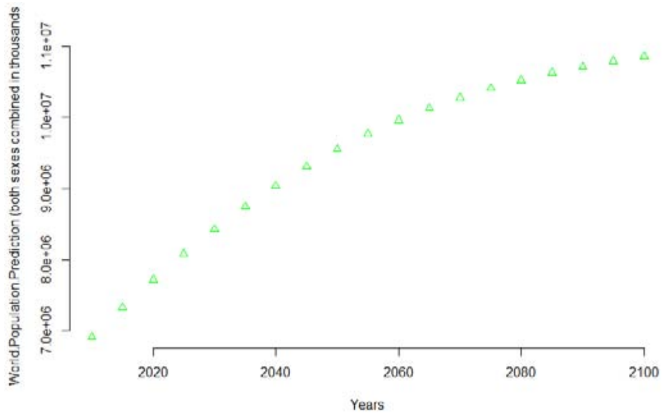
X1 (world population): Historical and prediction data are taken from the Department of Economic and Social Affairs of the Population Division in the United Nations (visit [55]) (see “Fig. 2” top). Predictions are from 2010 to 2100 for each 5 years period (2010, 2015, 2020,......,2100) (see “Fig. 2” bottom). This experimental input variable is preferred in this research because of two main reasons. Firstly, peak power demand is related with population in real life. Secondly, historical and projected data can be gathered easily. This experimental variable is sufficiently accurate in this RD3 stage (see also electronic supplementary material files: ESM).




```
Year=c(1950,1951,1952,1953,1954,1955,1956,1957,1958,1959,1960,1961,1962,1963,1964,1965,1966,1967,1968,1969,1970,1971,1972,1973,1974,1975,1976,1977,1978,1979,1980,1981,1982,1983,1984,1985,1986,1987,1988,1989,1990,1991,1992,1993,1994,1995,1996,1997,1998,1999,2000,2001,2002,2003,2004,2005,2006,2007,2008,2009,2010)

World.Population=c(2525779,2572851,2619292,2665865,2713172,2761651,2811572,2863043,2916030,2970396,3026003,3082830,3141072,3201178,3263739,3329122,3397475,3468522,3541675,3616109,3691173,3766754,3842874,3919182,3995305,4071020,4146136,4220817,4295665,4371528,4449049,4528235,4608962,4691560,4776393,4863602,4953377,5045316,5138215,5230452,5320817,5408909,5494900,5578865,5661086,5741822,5821017,5898688,5975304,6051478,6127700,6204147,6280854,6357992,6435706,6514095,6593228,6673106,6753649,6834722,6916183)

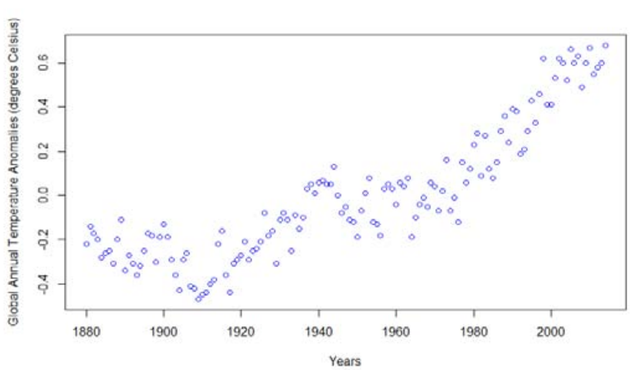
plot(Year, World.Population, xlab = "Years", ylab = "World Population (both sexes combined in thousands", pch=2, cex.main=1.5, frame.plot=FALSE, col="red")
```




Year=c(2010,2015,2020,2025,2030,2035,2040,2045,2050,2055,2060,2065,2070,2075,2080,2085,2090,2095,2100) World.Population.Prediction=c(6916183,7324782,7716749,8083413,8424937,8743447,9038687,9308438,9550945,9766475,9957399,10127007,10277339,10409149,10524161,10626467,10717401,10794252,10853849) plot(Year,World.Population.Prediction,xlab="Years",ylab="World.Population.Prediction (both sexes combined in thousands",pch=2,cex.main=1.5,frame.plot=FALSE,col="green")

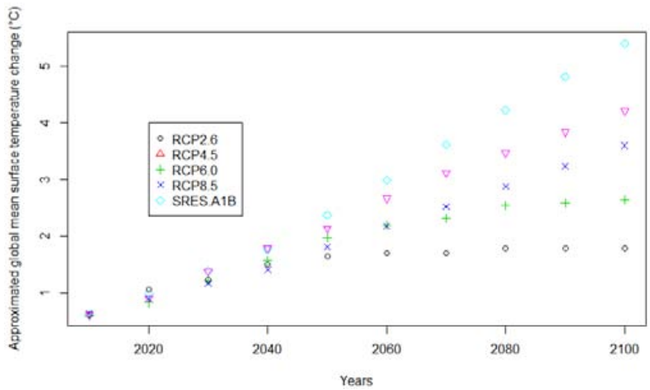
*Figure 2:* World population historical X1 (top) (country code: 900, year: 1950-2010: 61 data, access date: 05/07/2015), world population projection X1 (bottom) (year: 2011-2100: 18 data, access date: 06/07/2015), visualization generated by scatter graph of R (https://www.r-project.org/) and R Studio (https://www.rstudio.com/) script with data

X2 (global annual temperature anomalies in degrees Celsius: °C): Historical data are taken from the NASA Goddard Institute for Space Studies (GISS) Laboratory in the Earth Sciences Division (ESD) of National Aeronautics and Space Administration's (NASA) Goddard Space Flight Center (GSFC) (visit [56]) (see "Fig. 3" top). Projection data are gathered from the Intergovernmental Panel on Climate Change (IPCC), Annex II: Climate System Scenario Tables, Table AII.7.5. RCP8.5 (see [57]). There are five projections (RCP2.6, RCP4.5, RCP6.0, RCP8.5, SRES.A1B) in the IPCC report. The data are at 10 years period from 2010 to 2090 (see "Fig. 3" bottom). This experimental input variable is preferred in this research, because of three main reasons. Firstly, peak power demand is related with climatic conditions in real life. Secondly, historical and projected data can be taken easily. Finally, there are many academics and researchers, who work in climate change research area. This experimental variable is sufficiently accurate in this RD$^3$ stage (see also ESM).




Year=c(1880,1881,1882,1883,1884,1885,1886,1887,1888,1889,1890,1891,1892,1893,1894,1895,1896,1897,1898,1899,1900,1901,1902,1903,1904,1905,1906,1907,1908,1909,1910,1911,1912,1913,1914,1915,1916,1917,1918,1919,1920,1921,1922,1923,1924,1925,1926,1927,1928,1929,1930,1931,1932,1933,1934,1935,1936,1937,1938,1939,1940,1941,1942,1943,1944,1945,1946,1947,1948,1949,1950,1951,1952,1953,1954,1955,1956,1957,1958,1959,1960,1961,1962,1963,1964,1965,1966,1967,1968,1969,1970,1971,1972,1973,1974,1975,1976,1977,1978,1979,1980,1981,1982,1983,1984,1985,1986,1987,1988,1989,1990,1991,1992,1993,1994,1995,1996,1997,1998,1999,2000,2001,2002,2003,2004,2005,2006,2007,2008,2009,2010,2011,2012,2013,2014) Global.Annual.Temperature.Anomalies=c(-0.22,-0.14,-0.17,-0.2,-0.28,-0.26,-0.25,-0.31,-0.2,-0.11,-0.34,-0.27,-0.31,-0.36,-0.32,-0.25,-0.17,-0.18,-0.3,-0.19,-0.13,-0.19,-0.29,-0.36,-0.43,-0.29,-0.26,-0.41,-0.42,-0.47,-0.45,-0.44,-0.4,-0.38,-0.22,-0.16,-0.36,-0.44,-0.31,-0.29,-0.27,-0.21,-0.29,-0.25,-0.24,-0.21,-0.08,-0.18,-0.16,-0.31,-0.11,-0.08,-0.11,-0.25,-0.09,-0.15,-0.1,0.03,0.05,0.01,0.06,0.07,0.05,0.05,0.13,0,-0.08,-0.05,-0.11,-0.12,-0.19,-0.07,0.01,0.08,-0.12,-0.13,-0.18,0.03,0.05,0.03,-0.04,0.06,0.04,0.08,-0.19,-0.1,-0.04,-0.01,-0.05,0.06,0.04,-0.07,0.02,0.16,-0.07,-0.01,-

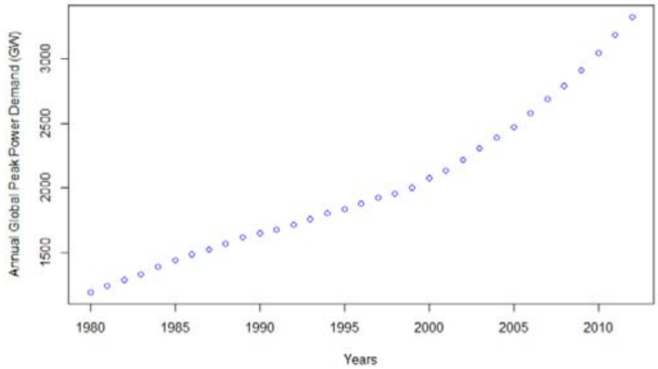
0.12,0.15,0.06,0.12,0.23,0.28,0.09,0.27,0.12,0.08,0.15,0.29,0.36,0.24,0.39,0.38,0.19,0.21,0.29,0.43,0.33,0.46,0.62,0.41,0.41,0.53, 0.62,0.6,0.52,0.66,0.6,0.63,0.49,0.6,0.67,0.55,0.58,0.6,0.68)
plot(Year, Global.Annual.Temperature.Anomalies, xlab = "Years", ylab = "Global Annual Temperature Anomalies (degrees Celsius)", col="blue")




Year=c(2010,2020,2030,2040,2050,2060,2070,2080,2090,2100)
RCP2.6=c(0.62,1.07,1.24,1.50,1.65,1.71,1.71,1.79,1.79,1.79)
RCP4.5=c(0.59,0.83,1.22,1.57,1.97,2.19,2.32,2.54,2.59,2.64)
RCP6.0=c(0.64,0.90,1.17,1.41,1.81,2.18,2.52,2.88,3.24,3.60)
RCP8.5=c(0.62,0.99,1.39,1.77,2.37,2.99,3.61,4.22,4.81,5.40)
SRES.A1B=c(0.62,0.91,1.38,1.79,2.14,2.67,3.12,3.47,3.84,4.21)
Temperature.Change=data.frame(RCP2.6, RCP4.5, RCP6.0, RCP8.5, SRES.A1B)
plot(Year, RCP8.5, xlab="Years", ylab="Approximated global mean surface temperature change (°C)", pch=5, col="5")
points(Year, RCP2.6, pch=1, col="1")
points(Year, RCP4.5, pch=3, col="3")
points(Year, RCP6.0, pch=4, col="4")
points(Year, SRES.A1B, pch=6, col="6")
legend(2020,4,c("RCP2.6","RCP4.5","RCP6.0","RCP8.5","SRES.A1B"),col=c(1,2,3,4,5),pch=c(1,2,3,4,5))

*Figure 3:* Global annual temperature anomalies in degrees Celsius (°C) historical X2 (top) (year: 1880-2014: 135 data, access date: 05/07/2015), projection X2 (bottom) (year: 2020-2090: 8 data per model, year: 2013), visualization generated by scatter graph of R and R Studio script with data

Y: (annual peak power load demand of the Global Grid: GW) (GW: gigawatt: 109 W: watt): An assumption is made according to some practical life experience (annual peak power load demand conversion coefficient is 60%) in this output variable. Historical data (total electricity installed capacity in million kilowatts) are taken from the U.S. Energy Information Administration (visit [58]) (see “Fig. 4”). This experimental output variable is preferred in this research because historical data can be gathered easily. This experimental variable is sufficiently accurate in this RD3 stage (see ESM).




```
Year=c(1980,1981,1982,1983,1984,1985,1986,1987,1988,1989,1990,1991,1992,1993,1994,1995,1996,1997,1998,1999,2000,2001,2002,2003,2004,2005,2006,2007,2008,2009,2010,2011,2012)
World.Electricity.Installed.Capacity.GW=c(1983,2071,2147,2217,2313,2399,2471,2542,2611,2702,2754,2797,2858,2928,3000,3055,3135,3202,3258,3338,3457,3560,3697,3846,3983,4123,4303,4478,4650,4852,5081,5314,5549)
Conversion=c(0.6)
World.Peak.Power.Demand.GW=World.Electricity.Installed.Capacity.GW*Conversion
plot(Year, World.Peak.Power.Demand.GW, xlab = "Years", ylab = "Annual Global Peak Power Demand (GW)", col="blue")
```

*Figure 4:* Annual peak power load demand of the Global Grid calculated based on the U.S. Energy Information Administration data, historical Y (year: 1980-2012: 33 data, access date: 21/08/2015), visualization generated by scatter graph of R and R Studio script with data

According to these data and conditions, modeling period is taken as 31 years (from 1980 to 2010). Prediction period is accepted as from 2011 to 2100 (90 years) with time intervals in prediction period of 10 years (2020, 2030,..., 2100). In other words, forecasting interval in this study is taken as 10 years in 100 years prediction period according to time intervals of input variables.

Seven experimental triangular membership functions for experimental core type 1 and interval type 2 Mamdani FIS on JuzzyOnline V2.0 are defined for inputs and output of this study (for details “Fig. 5”). Visual comparison of these membership functions are presented in “Fig. 6”. 49 experimental rules are defined in this study (for details “Fig. 7”). Website links of these core models are also given in this section. Details of these core models can be seen in these links. Moreover, these links can be copied and pasted to web browsers and details of these core models can be investigated. Several applications can also be done on these models on web browsers by online internet connection. Centroid defuzzification is used in this study. In computation method, AND connective t-Norm is selected as product and inference t-Norm is selected as product on JuzzyOnline V2.0.

| Experimental Core Type 1 Mamdani FIS Membership Functions | | | | |
|---|---|---|---|---|
| Experimental Inputs | | | | |
| Input 1: world population lower bound: 4440000, upper bound: 10900000 | | | | |
| membership function name | type | start | peak | stop |
| very very low | triangular | 4440000 | 4440000 | 5517000 |
| very low | triangular | 4440000 | 5517000 | 6594000 |
| low | triangular | 5517000 | 6594000 | 7670000 |
| moderate | triangular | 6594000 | 7670000 | 8747000 |
| high | triangular | 7670000 | 8747000 | 9824000 |
| very high | triangular | 8747000 | 9824000 | 10900000 |
| very very high | triangular | 9824000 | 10900000 | 10900000 |
| Input 2: global annual temperature anomalies (degrees Celsius: °C) lower bound: 0, upper bound: 6 | | | | |
| membership function name | type | start | peak | stop |
| almost the same | triangular | 0 | 0 | 1 |
| fairly hotter | triangular | 0 | 1 | 2 |
| rather hotter | triangular | 1 | 2 | 3 |
| hotter | triangular | 2 | 3 | 4 |
| very hotter | triangular | 3 | 4 | 5 |
| very very hotter | triangular | 4 | 5 | 6 |
| extremely hotter | triangular | 5 | 6 | 6 |
| Experimental Outputs | | | | |
| Output 1: annual peak power load demand of Global Grid (GW) lower bound: 1100, upper bound: 5500 | | | | |
| membership function name | type | start | peak | stop |
| very very low | triangular | 1100 | 1100 | 1835 |
| very low | triangular | 1100 | 1835 | 2568 |
| low | triangular | 1835 | 2550 | 3301 |
| moderate | triangular | 2568 | 3301 | 4034 |
| high | triangular | 3301 | 4034 | 4767 |
| very high | triangular | 4034 | 4767 | 5500 |
| very very high | triangular | 4767 | 5500 | 5500 |
| Experimental Core Interval Type 2 Mamdani FIS Membership Functions | | | | |
| Experimental Inputs | | | | |
| Input 1: world population lower bound: 4440000, upper bound: 10900000 | | | | |
| membership function name | type | start* | peak* | stop* |
| very very low | triangular | 4440000 | 4440000 | 5517000 |
| | | 4440000 | 4440000 | 5017000 |
| very low | triangular | 4440000 | 5517000 | 6594000 |
| | | 4940000 | 5517000 | 6094000 |
| low | triangular | 5517000 | 6594000 | 7670000 |
| | | 6017000 | 6594000 | 7170000 |
| moderate | triangular | 6594000 | 7670000 | 8747000 |
| | | 7094000 | 7670000 | 8247000 |
| high | triangular | 7670000 | 8747000 | 9824000 |
| | | 8170000 | 8747000 | 9324000 |

*Figure 5:* Experimental Core Type 1 & Interval Type 2 Mamdani FIS Membership Functions Of JuzzyOnline V2.0 Model

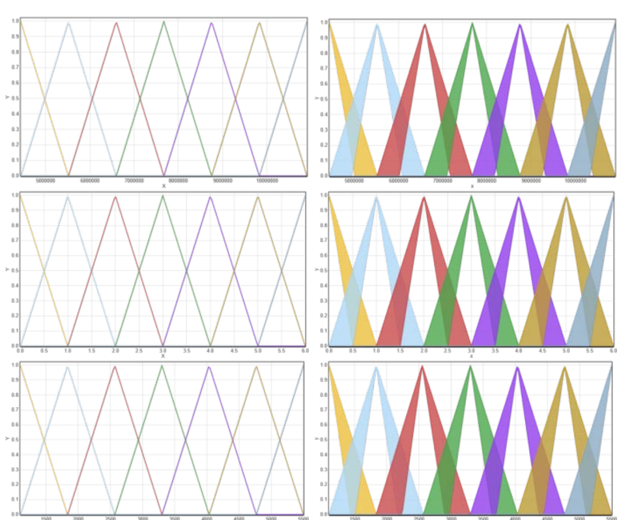


*Figure 6:* Visual comparisons of inputs and output membership functions, world population: X1 (top), global annual temperature anomalies: X2 (middle), annual peak power load demand of the Global Grid: Y (bottom), visualization generated by JuzzyOnline V2.0

| Rule | If | Input 1 | and | Input 2 | then | Output |
|---|---|---|---|---|---|---|
| 1 | If | very very low | and | almost the same | then | very very low |
| 2 | If | very very low | and | fairly hotter | then | very very low |
| 3 | If | very very low | and | rather hotter | then | very low |
| 4 | If | very very low | and | hotter | then | very low |
| 5 | If | very very low | and | very hotter | then | low |
| 6 | If | very very low | and | very very hotter | then | low |
| 7 | If | very very low | and | extremely hotter | then | moderate |
| 8 | If | very low | and | almost the same | then | very low |
| 9 | If | very low | and | fairly hotter | then | very low |
| 10 | If | very low | and | rather hotter | then | low |
| 11 | If | very low | and | hotter | then | low |
| 12 | If | very low | and | very hotter | then | moderate |
| 13 | If | very low | and | very very hotter | then | moderate |
| 14 | If | very low | and | extremely hotter | then | high |
| 15 | If | low | and | almost the same | then | low |
| 16 | If | low | and | fairly hotter | then | low |
| 17 | If | low | and | rather hotter | then | moderate |
| 18 | If | low | and | hotter | then | moderate |
| 19 | If | low | and | very hotter | then | high |
| 20 | If | low | and | very very hotter | then | high |
| 21 | If | low | and | extremely hotter | then | very high |
| 22 | If | moderate | and | almost the same | then | moderate |
| 23 | If | moderate | and | fairly hotter | then | moderate |
| 24 | If | moderate | and | rather hotter | then | high |
| 25 | If | moderate | and | hotter | then | moderate |
| 26 | If | moderate | and | very hotter | then | high |
| 27 | If | moderate | and | very very hotter | then | high |
| 28 | If | moderate | and | extremely hotter | then | very high |
| 29 | If | high | and | almost the same | then | high |
| 30 | If | high | and | fairly hotter | then | high |
| 31 | If | high | and | rather hotter | then | high |
| 32 | If | high | and | hotter | then | high |
| 33 | If | high | and | very hotter | then | high |
| 34 | If | high | and | very very hotter | then | high |
| 35 | If | high | and | extremely hotter | then | very high |
| 36 | If | very high | and | almost the same | then | high |
| 37 | If | very high | and | fairly hotter | then | high |
| 38 | If | very high | and | rather hotter | then | high |
| 39 | If | very high | and | hotter | then | very high |
| 40 | If | very high | and | very hotter | then | very high |
| 41 | If | very high | and | very very hotter | then | very high |
| 42 | If | very high | and | extremely hotter | then | very very high |
| 43 | If | very very high | and | almost the same | then | high |

*Figure 7:* Experimental Core Type 1 & Interval Type 2 Mamdani FIS JuzzyOnline V2.0 Rules*

JuzzyOnline V2.0 models are also presented as in the "Tab. 1" and "Tab. 2". Readers can copy and paste to their internet browsers and run the models.

*Table 1:* JuzzyOnline V2.0 Experimental Type 1 Mamdani FIS Peak Power Load Fore-casting of Global Grid Website Link

| |
|---|
| http://ritweb.cloudapp.net:8080/JuzzyOnline2/gensys?type=1&name=Experimen-tal%20Type%201%20Mamdani%20FIS%20Peak%20Power%20Load%20Forecast-ing%20of%20Global%20Grid&input=world%20population&lb=4440000.0&ub=1.09E7&mfnb=7&mf=very%20very%20low&fun=triangular&p=4440000.0_4440000.0_5517000.0&mf=very%20low&fun=triangular&p=4440000.0_5517000.0_6594000.0&mf=low&fun=triangular&p=5517000.0_6594000.0_7670000.0&mf=moderate&fun=triangular&p=6594000.0_7670000.0_8747000.0&mf=high&fun=triangular&p=7670000.0_8747000.0_9824000.0&mf=very%20high&fun=triangular&p=8747000.0_9824000.0_1.09E7&mf=very%20very%20high&fun=triangular&p=9824000.0_1.09E7_1.09E7&input=global%20annual%20temperature%20anomalies&lb=0.0&ub=6.0&mfnb=7&mf=almost%20the%20same&fun=triangular&p=0.0_0.0_1.0&mf=fairly%20hotter&fun=triangular&p=0.0_1.0_2.0&mf=rather%20hot-ter&fun=triangular&p=1.0_2.0_3.0&mf=hotter&fun=triangular&p=2.0_3.0_4.0&mf=very%20hotter&fun=triangular&p=3.0_4.0_5.0&mf=very%20very%20hotter&fun=triangular&p=4.0_5.0_6.0&mf=extremely%20hotter&fun=triangular&p=5.0_6.0_6.0&output=annual%20peak%20power%20d |

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emand%20of%20Global%20Grid&lb=1100.0&ub=5500.0&mfnb=7&mf=
very%20very%20low&fun=triangular&p=1100.0_1100.0_1835.0&mf=ver
y%20low&fun=triangu-lar&p=1100.0_1835.0_2568.0&mf=low&fun=trian
gu-
lar&p=1835.0_2568.0_3301.0&mf=moderate&fun=triangular&p=2568.0_
3301.0_4034.0&mf=high&fun=triangular&p=3301.0_4034.0_4767.0&mf
=very%20high&fun=triangular&p=4034.0_4767.0_5500.0&mf=very%20v
ery%20high&fun=triangular&p=4767.0_5500.0_5500.0&if=0_0_1_0&the
n=0_0&if=0_0_1_1&then=0_0&if=0_0_1_2&then=0_1&if=0_0_1_3&the
n=0_1&if=0_0_1_4&then=0_2&if=0_0_1_5&then=0_2&if=0_0_1_6&the
n=0_3&if=0_1_1_0&then=0_1&if=0_1_1_1&then=0_1&if=0_1_1_2&the
n=0_2&if=0_1_1_3&then=0_2&if=0_1_1_4&then=0_3&if=0_1_1_5&the
n=0_3&if=0_1_1_6&then=0_4&if=0_2_1_0&then=0_2&if=0_2_1_1&the
n=0_2&if=0_2_1_2&then=0_3&if=0_2_1_3&then=0_3&if=0_2_1_4&the
n=0_4&if=0_2_1_5&then=0_4&if=0_2_1_6&then=0_5&if=0_3_1_0&the
n=0_3&if=0_3_1_1&then=0_3&if=0_3_1_2&then=0_4&if=0_3_1_3&the
n=0_3&if=0_3_1_4&then=0_4&if=0_3_1_5&then=0_4&if=0_3_1_6&the
n=0_5&if=0_4_1_0&then=0_4&if=0_4_1_1&then=0_4&if=0_4_1_2&the
n=0_4&if=0_4_1_3&then=0_4&if=0_4_1_4&then=0_4&if=0_4_1_5&the
n=0_4&if=0_4_1_6&then=0_5&if=0_5_1_0&then=0_4&if=0_5_1_1&the
n=0_4&if=0_5_1_1&then=0_4&if=0_5_1_3&then=0_5&if=0_5_1_4&the
n=0_5&if=0_5_1_5&then=0_5&if=0_5_1_6&then=0_6&if=0_6_1_0&the
n=0_4&if=0_6_1_1&then=0_5&if=0_6_1_2&then=0_5&if=0_6_1_3&the
n=0_6&if=0_6_1_4&then=0_6&if=0_6_1_5&then=0_6&if=0_6_1_6&the
n=0_6&actn=p&itn=p
```


Experimental core type 1 and interval type 2 Mamdani FIS models on the JuzzyOnline V2.0 are run for each annual data and results are found, copied and recorded on a Microsoft Excel 2007 ∗.xls file (http://www.microsoft.com). An Apache OpenOffice Calc ∗.ods file (http://www.openoffice.org/) is also generated from this file (see ESM). Historical annual peak power load demand of the Global Grid, experimental core type 1 Mamdani FIS based Global Grid peak power load forecasting model (ECT1MFISGGPP) findings on historical data and predictions of experimental core interval type 2 Mamdani FIS based Global Grid peak power load forecasting model (ECIT2MFISGGPP) on historical data are presented in "Fig. 8" (see ESM).

A few prediction performance assessment measures are tested in this study. These measures (absolute percentage error, maximum absolute percentage error, mean absolute percentage error) are mostly seen in literature and calculated according to equation 1 to 3.

Absolute percentage error (APE):

$$APE_t = \frac{(|Actual_t - Predicted_t|)}{(Actual_t)} \tag{1}$$

Maximum absolute percentage error (MAP):

$$MAP = max(APE_t) \tag{2}$$

Mean absolute percentage error (MAPE):

$$MAPE = \frac{1}{n}\sum_1^n (APE_t) \tag{3}$$

Where actual shows historical annual electricity demand of the Global Grid, predicted shows forecasted annual electricity demand of the Global Grid, t stands for year, and n stands for total number of years. Values of these prediction performance assessment measures are presented very clearly in ESM and showed by "Fig. 9". APE of core type 1 models ranges between 0,32 and 0,46, so that MAP of this model is found as 0,46. MAPE of this model is calculated as 0, 36 (see ESM). APE of core interval type 2 models ranges between 0,29 and 0,46, so that MAP of this model is found as 0,46. MAPE of this model is calculated as 0,36 (see ESM). These measures shows that both of these models need serious improvement efforts. Before spending time and efforts on these FIS model enhancements, some simple adjustments are made according to following approaches and adjusted models are also compared. It is hoped that these adjusted models will help improvements of these core FIS models in future studies.

Adjusted model approach 1: First, differences between actual values and predicted values are calculated in this approach. Second, arithmetic average of these values is calculated in this data series. Core type 1 and interval type 2 model predictions are adjusted by summation of this value. New models based on this procedure is called experimental adjusted 1 type 1 Mamdani FIS based Global Grid peak power load forecasting model (EA1T1MFISGGPP) and experimental adjusted 1 interval type 2 Mamdani FIS based Global Grid peak power load forecasting model (EA1IT2MFISGGPP). Predictions of these adjusted 1 models are presented in Figure 6. APE of adjusted 1 type 1 model ranges between 0,00 and 0,27, so that MAP of this model is found as 0,27. MAPE of this model is calculated as 0,11 (see ESM). APE of adjusted 1 interval type 2 model ranges between 0,00 and 0,25, so that MAP of this model is found as 0,25. MAPE of this model is calculated as 0,11 (see ESM and "Fig. 9").

Adjusted model approach 2: Minimum value amongst values of first step of adjusted model approach 1 procedure is found in this approach. Core type 1 and interval type 2 model predictions are adjusted by summation of this value. New models based on this procedure is called EA2T1MFISGGPP & EA2IT2MFISGGPP. Predictions of these adjusted 2 models are presented in "Fig. 8". APE of adjusted 2 type 1 model ranges between 0,00 and 0,33, so that MAP of this model is found as 0,33. MAPE of this model is calculated as 0,14 (see ESM). APE of adjusted 2 interval type 2 model ranges between 0,00 and 0,32, so that MAP of this model is found as 0,32. MAPE of this model is calculated as 0,13 (see ESM and "Fig. 9").

Adjusted model approach 3: Maximum value amongst values of first step of adjusted model approach 1 procedure is found in this approach. Core type 1 and interval type 2 model predictions are adjusted by summation of this value. New models based on this procedure is called EA3T1MFISGGPP & EA3IT2MFISGGPP. Predictions of these adjusted 3 models are presented in "Fig. 8". APE of adjusted 3 type 1 model ranges between 0,00 and 0,84, so that MAP of this model is found as 0,84. MAPE of this model is calculated as 0,41 (see ESM). APE of adjusted 3 interval type 2 model ranges between 0,00 and 0,83, so that MAP of this model is found as 0,83. MAPE of this model is calculated as 0,41 (see ESM and "Fig. 9").

Adjusted model approach 4: First, ratio values between actual values and predicted values are calculated in this approach. Second, arithmetic average of these values is calculated in this data series. Core type 1 and interval type 2 model predictions are adjusted by multiplication of this value. New models based on this procedure is called EA4T1MFISGGPP & EA4IT2MFISGGPP. Predictions of these adjusted 4 models are presented in "Fig. 8". APE of adjusted 4 type 1 model ranges between 0,00 and 0,15, so that MAP of this model is found as 0,15. MAPE of this model is calculated as 0,04 (see ESM). APE of adjusted 4 interval type 2 model ranges between 0,00 and 0,15, so that MAP of this model is found as 0,15. MAPE of this model is calculated as 0,01 (see ESM and "Fig. 9").

Adjusted model approach 5: Minimum value amongst values of first step of adjusted model approach 4 procedure is found in this approach. Core type 1 and interval type 2 model predictions are adjusted by multiplication of this value. New models based on this procedure are called EA5T1MFISGGPP & EA5IT2MFISGGPP. Predictions of these adjusted 5 models are presented in "Fig. 8". APE of adjusted 5 type 1 model ranges between 0,00 and 0,20, so that MAP of this model is found as 0,20. MAPE of this model is calculated as 0,06 (see ESM). APE of adjusted 5 interval type 2 model ranges between 0,00 and 0,23, so that MAP of this model is found as 0,23. MAPE of this model is calculated as 0,09 (see ESM and "Fig. 9").

Adjusted model approach 6: Maximum value amongst values of first step of adjusted model approach 4 procedure is found in this approach. Core type 1 and interval type 2 model predictions are adjusted by multiplication of this value. New models based on this procedure are called EA6T1MFISGGPP & EA6IT2MFISGGPP. Predictions of these adjusted 6 models are presented in "Fig. 8". APE of adjusted 6 type 1 model ranges between 0,00 and 0,25, so that MAP of this model is found as 0,25. MAPE of this model is calculated as 0,18 (see ESM). APE of adjusted 6 interval type 2 model ranges between 0,00 and 0,31, so that MAP of this model is found as 0,31. MAPE of this model is calculated as 0,18 (see ESM and "Fig. 9").

Adjusted model approach 7: Most repeated or observed or frequent value (mode) amongst values of first step of adjusted model approach 4 procedure is found in this approach (mode of a data series). Core type 1 and interval type 2 model predictions are adjusted by multiplication of this value. New models based on this procedure are called EA7T1MFISGGPP & EA7IT2MFISGGPP. Predictions of these adjusted 7 models are presented in "Fig. 8". APE of adjusted 7 type 1 model ranges between 0,00 and 0,20, so that MAP of this model is found as 0,20. MAPE of this model is calculated as 0,06 (see ESM). APE of adjusted 7 interval type 2 model ranges between 0,00 and 0,18, so that MAP of this model is found as 0,18. MAPE of this model is calculated as 0,04 (see ESM and “Fig. 9”).

Adjusted model approach 8: Mid value (median) amongst values of first step of adjusted model approach 4 procedure is found in this approach (median of a data series). Core type 1 and interval type 2 model predictions are adjusted by multiplication of this value. New models based on this procedure are called EA8T1MFISGGPP & EA8IT2MFISGGPP. Predictions of these adjusted 8 models are presented in “Fig. 8”. APE of the adjusted 8 type 1 model ranges between 0,00 and 0,17, so that MAP of this model is found as 0,17. MAPE of this model is calculated as 0,04 (see ESM). APE of adjusted 8 interval type 2 model ranges between 0,00 and 0,17, so that MAP of this model is found as 0,17. MAPE of this model is calculated as 0,04 (see ESM and “Fig. 9”).

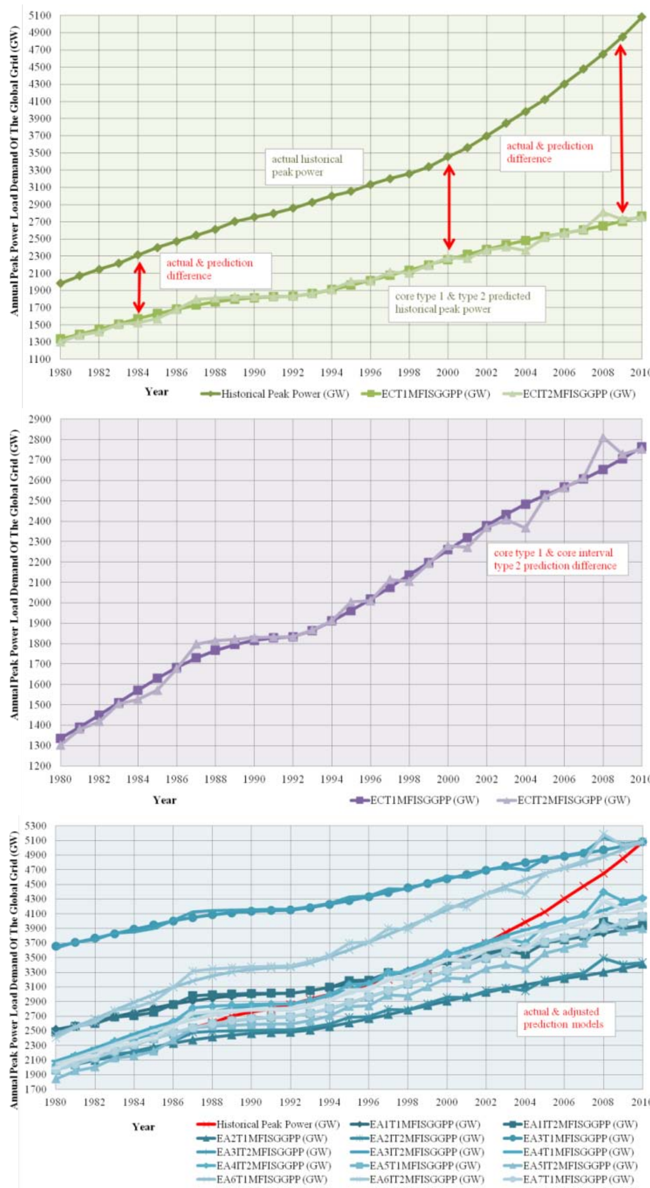
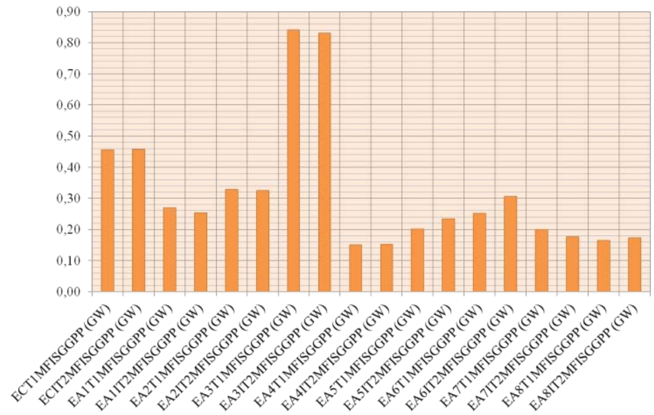



*Figure 8:* Historical annual peak power load demand of the Global Grid & predictions on historical data by experimental core type 1 and interval type 2 Mamdani FIS based Global Grid peak power load forecasting models (top), predictions on historical data by experimental core type 1 and interval type 2 Mamdani FIS based Global Grid peak power load forecasting models (middle), historical actual annual peak power load demand of the Global Grid & all adjusted models (bottom), visualization generated by the scatter with straight lines chart of the Microsoft Office Excel 2007 (http://www.microsoft.com)

Prediction performance assessment shows that best fit model for annual peak power load demand projection of the Global Grid is the fourth adjusted models (ratio based adjustment) (EA4T1MFISGGPP & EA4IT2MFIS-GGPP) with their 0,15 MAP and 0,04 MAPE performance values.



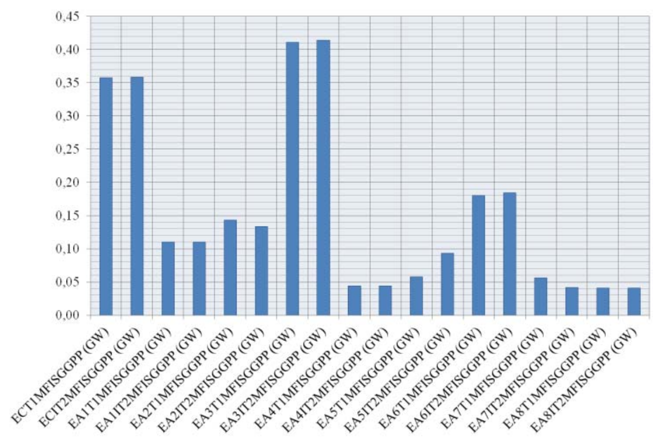




*Figure 7:* Core and adjusted models MAP (top) & MAPE (bottom), visualization generated by the 2-D clustered column chart of the Microsoft Office Excel 2007

This comparison study proves that core type 1 and interval type 2 Mamdani FIS models have to be improved for getting better predictions. However, long term forecasts (100 years) can be calculated with all of these models by their current capabilities. It is recommended that predictions should be made with core and best performed adjusted models.

## IV. Conclusions and Future Work

This research paper defines an important real world problem and its research study. Afterwards, the first comparable experimental FIS models (type 1 and interval type 2) are constructed by JuzzyOnline V2.0. Prediction performances of these experimental core models are presented and compared with each other. Two mostly used prediction performances (maximum absolute percentage error: MAP, mean absolute percentage error: MAPE) are preferred for comparison purposes. Historical annual peak power load demand of the Global Grid (GW) data, predicted/forecasted historical annual peak power load demand of the Global Grid (GW) values, and absolute percentage errors (APE) are clearly given for future research studies and other researchers. Core models are improved by help of some very simple and primitive mathematical approaches. Some of these adjusted models perform well. Author plans to continue working in this research topic. All possible variables will be investigated and all data for these variables will be found and analyzed in few years. All Mamdani FIS rules will be studied and found in near future. All membership functions will be defined and investigated during this period. All verbal definitions will be studied and defined by a worldwide research study. An automatic data gathering and predicting tool (acronym: G2P3S: global grid peak power prediction systems) will be designed and developed under a Global Grid Prediction Systems (G2PSs) (see [59]). G2P3S will not work only one model, but it is aimed to be working on several models at the same time. For instance, core type 1 and type 2 models and adjusted models are all used and presented concurrently on it.

This proposed tool will be presented on annual basis to the world on a website.

## V. Acknowledgements

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25. Hindawi Publishing Corporation, http://www.hindawi.com/
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