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Study Of Integrating Demand Side Management Potential To Power Generation Planning Through Load Forecasting

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Abstrak

Studi integrasi potensi Demand Side Management (DSM) telah dilakukan terhadap reduksi peramalan beban tenaga listrik jangka panjang pada sistem ketenagalistrikan di Indonesia dengan menggunakan model Indonesia Energy Outlook by System Dynamic (INOSYD) dan metode Jaringan Syaraf Tiruan (JST), dengan periode tahun studi 2005-2021. DSM merupakan suatu proses pengelolaan konsumsi energi, untuk mengoptimasikan ketersediaan dan perencanaan pengembangan sumberdaya energi. Aplikasi DSM yang dilakukan dalam penelitian ini diterapkan disisi konsumen untuk menekan dan menghemat jumlah konsumsi energi, sehingga akan mempengaruhi dan menurunkan hasil peramalan beban puncak tenaga listrik. Dalam paper ini pertama-tama telah dilakukan studi peramalan beban tenaga listrik jangka panjang dengan model INOSYD, metode JST dan Model for Analysis of Energy Demand (MAED) sebagai pembanding, dimana diperoleh hasil perhitungan laju kenaikan beban tahunan rata-rata masing-masing sekitar 4,60% (INOSYD) ; 7,16% (JST) dan 6,87% (MAED) selama periode tahun studi. Selanjutnya dilakukan studi pengaruh DSM dengan penghematan konsumsi energi pada sektor rumah tangga (residential) sebesar 5% dan 10% terhadap hasil peramalan beban tenaga listrik jangka panjang, dengan menggunakan model INOSYD dan metode JST. Hasil studi memperlihatkan bahwa aktivitas DSM pada sektor rumah tangga sebesar 5% dan 10% dengan model INOSYD akan menurunkan hasil peramalan beban puncak rata-rata masing-masing sebesar 4,95% dan 9,90% selama periode tahun studi, sedangkan jika digunakan metode JST akan menurunkan hasil peramalan beban puncak rata-rata masing-masing sebesar 2,74% dan 5,36%.

Kata kunci: *Demand side management, peramalan beban, INOSYD dan JST.*

Abstract

A study has been done on the potential integration of Demand Side Management (DSM) to the reduction of electric power peak load forecasting in the Indonesian electric system by using the Indonesia Energy Outlook by System Dynamic (INOSYD) model and Artificial Neural Network (ANN) method, within the study period of 2005-2021. DSM is the process of managing the consumption of energy, generally to optimize availability and development plan of energy resources. DSM application in this research refers to actions taken on the customer's side of the matter to change the amount or timing of energy consumption, therefore it influences the reduction of the long-range forecasting of electricity peak load. In this paper, the long-term load forecasting is studied by using INOSYD model, JST method and Model for Analysis of Energy Demand (MAED) as comparison, where the calculation results of average annual load growth rate are around 4.60% (INOSYD) ; 7.16% (JST) and 6.87% (MAED) respectively. Afterwards, the influence of DSM by an effort to reduce energy consumption of residential sector by an amount of 5% and 10% respectively, with the respect to the long-term load forecasting by using INOSYD model and ANN method is performed. The study results show that DSM application at residential (household) sector at an amount of 5% and 10% by using INOSYD model will reduce the average long-term load forecasting by about 4.95% and 9.90% respectively, meanwhile ANN method will reduce the average long-term load forecasting by about 2.74% and 5.36% respectively.

Keywords: *Demand side management, load forecasting, INOSYD and ANN.*

1. Introduction.

In the electricity system planning process, a load forecast is the most important activity (component), as forecasting the electricity needs is the first step of the planning process itself. The accuracy of the load forecast value will influence the number of generator have to be built. Therefore in the load forecast

process, choosing the appropriate model and method is the main step in order to gain the accurate forecast value. Variables which commonly distinguish the load forecast are GDP, electricity ratio, energy value, population, etc. To make a load forecast and to integrate it into the planning process requires a mathematical formula from the accurate (exact) load curve, in this case the Snyder Model [1] is used and to integrate DSM into the load forecast, will be much better use a special model, that can implement DSM on load curve model [2]. As no load forecast model can integrate DSM activities into a planning process, DSM potential forecast activity and electric power forecast are still separated.

This paper will explain about the integration of those DSM potential to the load forecast. Comparison analyses long term load forecast result with variety method will be done, they are *Indonesia Energy Outlook by System Dynamic* (INOSYD), *Artificial Neural Network* (ANN), and simulation for *Model for Analysis of Energy Demand* (MAED) within the study period of 2005-2021.

Furthermore, integration potential Demand Side Management (DSM) study has been done to the reduction of long term load forecasting at the electric power in Indonesia by using INOSYD Model and *Artificial Neural Network* (ANN). The simulation of energy efficiency reduction to household sector is 5% and 10% to the result of long term electrical power load forecasting.

2. Power System Planning and Demand Side Management (DSM).

In the power system planning process some steps performed as shown on the Figure 1. There are two ways to put the DSM potential into the planning process: The first by calculating the Capacity Benefit from DSM and second by integrating DSM potential into load forecast. Capacity Benefit Method is reduction of peak load resulted from DSM activity, where it is assumed equivalent with new generator unit capacity which will be put into the total capacity unit generator [3].

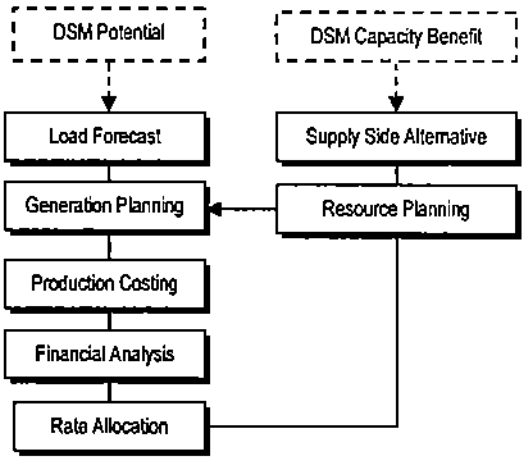

Figure 1.
Steps For Electricity Power System Planning.

DSM is an activity controlling the electricity use on the demand side to adapt availability electricity power in supply side. Some main activities generally performed on the DSM program are: *Peak Clipping, Valley Filling, Strategic Conservation, Strategic Load Growth* and *Load Shifting*. Peak Clipping and Load Shifting are financially the most advantage DSM program for electric company because these programs can reduce peak load maximally. The reduction of peak load will cut down the investment of new unit generator [4],[5]. In this research the DSM activity conducted is Strategic Conservation.

3. Model INOSYD

Indonesia Energy Outlook by System Dynamic (INOSYD) is at the beginning developed by *Energy Research Centre of University of Indonesia* (PEUI). The diagram of INOSYD dynamic flowchart can be shown in Figure 2.

Model system energy consists of energy availability sector and energy demand sector where *Reference Energy System* (RES) is included. Energy demand side is divided into several following sectors: industry, commercial, household, transportation and electricity. The whole

sectors are dynamically modified. The economy macro module consists of *Social Accounting Matrix* (SAM), where the IO table and PDB projection are inside the SAM and population, energy values are exogenous variable [6],[7]. INOSYD is a program of a model dynamic system energy national written by the so called *Powersim Software* using dynamic system methodology.

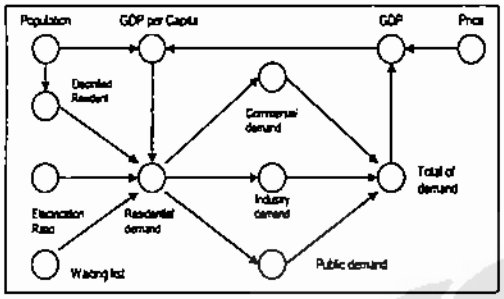

Figure 2.
INOSYD Dynamic Model Flow Diagram [7].

In such methodology, model of electricity needs of each sector depends on residential model formulated as follow:

$$ERes(kWh) = e^{a} * \left(\frac{GDP}{Pop}\right)^{b} * \left(\frac{Pop}{F * ER}\right)^{c}$$

where:
$ERes$ = electricity residential demand
GDP = Gross Domestic Product
Pop = population
F = persons in a family
ER = electrification ratio
a,b,c = regression constants.

Figure 2 shows that residential sector is a determinant element of model.

To determine electricity needs for other sectors, conducted by elasticity calculation between electricity needs residential sector to other sectors. The required data in forecasting electricity needs by using INOSYD dynamic model are: GDP, population, electrification ratio, persons in a family, elasticity residential sector to social needs, industry & commercial, losses of the transmission & distribution, data history of electricity use in each sector and electricity price.

4. Artificial Neural Network (ANN).

Artificial Neural Network (ANN) is a part of *Artificial Intelligence* (AI) system which is one of artificial representation from human brain trying to simulate learning process to the human brain itself.

The following factors will influence load forecast electricity power in the future:

a. Gross Domestic Product (GDP) per capita
b. Amount of population
c. Amount of household
d. Electrification Ratio
e. Amount of CO_2 pollution
f. The average of crude oil price
g. The average of coal price
h. Final energy consumption
i. Needs of final energy in industrial sector
j. The average of electricity price.

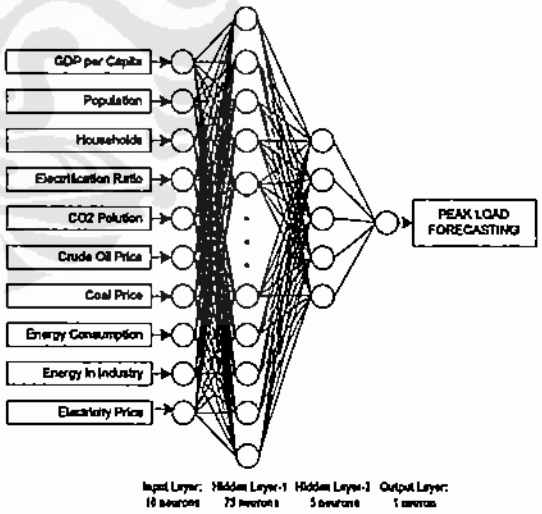

Figure 3.
Design of Artificial Neural Network (ANN) [8].

In this ANN method, it is used 1 input layer, 2 hidden layers, and finally 1 output layer. The simulation on load forecast with ANN using back-propagation learning method is done by using the Matlab Vers.7 Release 14 software.

5. MAED Simulation.

MAED (*Model for Analysis of Energy Demand*) is a simulation model designed to evaluate energy demand of a country or region for a middle and long term. This model adapted by *International Atomic Energy Agency* (IAEA) from MEDEE-2 model developed for *International Institute for Applied Systems Analysis* (IIASA). It is to analyze demand evolution for the whole energy, included electrical energy of a country or region. The MAED general equation for energy needs calculation is as followed [8]:

$$ED_t = [ED/DF]_{t=0} * ImpR_t * DF_t$$

where:

ED_t = energy needs for the year-t
$[ED/DF]_{t=0}$ = energy intensity of basic year
$ImpR_t$ = coefficient of energy intensity improvement
DF_t = driving factor for the year-t.

6. Simulation Result of Load Forecast.

Load forecast model used for this study are INOSYD, ANN & MAED. INOSYD & ANN are the first result of the research from the writer & team, while MAED created by other team stand as comparison to find the accuracy of forecast result. The simulation result of peak load forecast research for the period 2005-2021 as seen on the Table 1 and Figure 4.

The result of peak load forecast in Indonesia for the beginning of study year (2005) based on calculation with INOSYD model; ANN method & MAED simulation gained of each 20,549 MW; 16,516 MW & 22,565 MW.

There is no big different the result of peak load forecast at the end of study year (2021) using ANN method with the result of MAED simulation, each about 61,188 MW and 58,489 MW, whereas the forecast from INOSYD model slightly different which is 40,599 MW.

Based on the real peak load in 2004 about 18,896 MW, it obtained the yearly load increase calculation for average amount of 4.60%; 7.16% and 6.87% each based on INOSYD, JST and MAED for the study period of 2005-2021.

Table 1.
Peak Load Forecasting in Indonesia (MW).

Year	INOSYD	ANN	MAED
2005	20549	16516	22565
2006	21409	17854	23912
2007	22304	19333	25340
2008	23237	20890	26853
2009	24213	22567	28457
2010	25243	24482	30974
2011	26330	26472	32824
2012	27478	28580	34784
2013	28689	30936	36861
2014	29962	33443	39063
2015	31291	36157	41269
2016	32679	39557	43733
2017	34129	43277	46345
2018	35643	47228	49112
2019	37224	51510	52045
2020	38875	56060	55193
2021	40599	61188	58489

Note: Real peak load for the year 2004: 18896 MW.

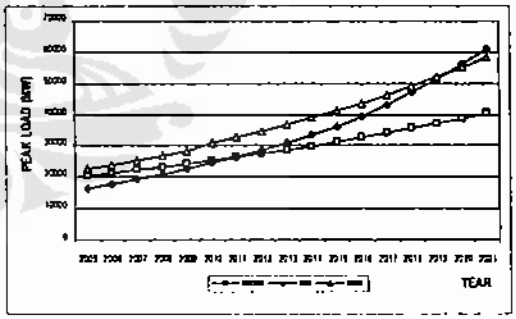

Figure 4.
The Approximation Peak Load Forecast in Indonesia on 2005-2021.

As seen from load forecast result in the first 10 years (2005 to 2015), the three models almost have the similar trend. However for the next five years on 2016 to 2021 the INOSYD result is lower from the other two models. Because the INOSYD use the residential consumptions as the reference of grows in other sectors. The INOSYD assumes, the electric energy

consumption is influenced by the single person characteristic as a user. A user on a residential is also a user on other sector. Therefore INOSYD is more appropriate for load forecast which integrate DSM into an electric energy load forecast like this study, because the effectiveness of DSM are fully influenced by the electric consumer characteristic.

7. DSM Simulation Result.

The DSM program which being implemented in this study is a Strategic Conservation which is the consumer does the efficiency of the energy consumption in a residential sector is assumed about 5% and 10%. Thereafter with INOSYD and ANN models, we monitor the impact to the peak load decrease.

Table 2.
The Reduction of Peak Load Forecast with INOSYD Model to DSM on Residential Sector about 5% and 10%.

Year	INOSYD No DSM	INOSYD with DSM 5%		INOSYD with DSM 10%	
	Load	Load	Reduce	Load	Reduce
	(Mwe)	(Mwe)	%	(Mwe)	%
2005	20549	19543	4.90	18537	9.79
2006	21409	20359	4.90	19309	9.81
2007	22304	21209	4.91	20114	9.82
2008	23237	22094	4.92	20951	9.84
2009	24213	23021	4.92	21829	9.85
2010	25243	23999	4.93	22754	9.86
2011	26330	25030	4.94	23730	9.87
2012	27478	26119	4.95	24761	9.89
2013	28689	27269	4.95	25849	9.90
2014	29962	28477	4.96	26992	9.91
2015	31291	29739	4.96	28186	9.92
2016	32679	31056	4.97	29433	9.93
2017	34129	32432	4.97	30734	9.95
2018	35643	33868	4.98	32094	9.96
2019	37224	35368	4.99	33513	9.97
2020	38875	36935	4.99	34995	9.98
2021	40599	38571	5.00	36543	9.99
Average load reduction (%)			4.95		9.90

If the reduction of the energy consumption is not followed by the decreasing of the peak load, the electricity company will not get the benefit, in fact the electric company will loose their income because of the less energy sold.

The results of study reflect the DSM activity by reduction of energy consumption on residential sector about 5% and 10% with INOSYD model will decrease the average peak load forecast about 4.95% and 9.90% respectively during study period (see Table 2 and Figure 5). Whereas if ANN method used, the implementation of residential sector DSM about 5% and 10% will decrease the average peak load forecast about 2.74% and 5.36% respectively (see Table 3 and Figure 5).

Table 3.
The Decrease of Peak Load Forecast with the ANN Method to DSM on Residential Sector about 5% and 10% Energy Reduction.

Year	ANN	ANN - DSM 5%		ANN-DSM 10%	
	Load	Load	Reduce	Load	Reduce
	(MW)	(MW)	%	(MW)	%
2005	16516	15860	3.97	15202	7.96
2006	17854	17179	3.78	16504	7.56
2007	19333	18640	3.58	17945	7.18
2008	20890	20177	3.41	19465	6.82
2009	22567	21836	3.24	21105	6.48
2010	24482	23732	3.06	22982	6.13
2011	26472	25702	2.91	24933	5.81
2012	28580	27791	2.76	27003	5.52
2013	30936	30127	2.61	29319	5.23
2014	33443	32614	2.48	31786	4.95
2015	36157	35309	2.35	34461	4.69
2016	39557	38684	2.21	37813	4.41
2017	43277	42380	2.07	41486	4.14
2018	47228	46307	1.95	45388	3.90
2019	51510	50090	2.76	49622	3.67
2020	56060	55090	1.73	54122	3.46
2021	61188	60187	1.64	59190	3.26
Average load reduction (%)			2.74		5.36

It reflects from the result of INOSYD give a lower peak load forecast number. And this is the accurate result for DSM activity, because if a whole family has a habit to save the energy, they will do the

same thing in their workplace (in industrial sector and office).

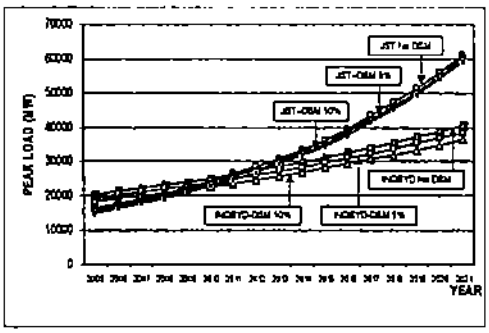

Figure 5.
DSM Influence on the Load Forecast Result in Indonesia with INOSYD and ANN.

8. Conclusion.

Integration Demand Side Management potential in electric system planning process can be done in two ways i.e. calculating the capacity benefit or load forecast integration. Obviously the capacity benefit integration is much simpler, but it has a minimum accuracy. On the other hand the integration with the load forecast will give a better performance if the Load Duration Curve using mathematical formulas which include a base load value, peak load and energy total, because the DSM activity will always influence those three values.

The Demand Side Management (DSM) application in the residential sector about 5% and 10% energy reduction with INOSYD model will decrease the average peak load forecast to 4.95% and 9.90% respectively during the study period, on the other hand, if the ANN method used will decrease the average peak load forecast to 2.74% and 5.36% respectively. Obviously the DSM application on the household sector quite influences to decrease the result of long range electric power peak load forecast in Indonesia.

For the future research, the mathematical load model which is influenced by base load, peak load, and total energy have to be made and put in INOSYD and ANN (or other load forecast model) for better DSM integration in load forecast.

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