An intelligent switch with back-propagation neural network based hybrid power system

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Abstract. The consumption of conventional energy such as fossil fuels plays the critical role in the global warming issues. The carbon dioxide, methane, nitrous oxide, etc. could lead the greenhouse effects and change the climate pattern. In fact, 77% of the electrical energy is generated from fossil fuels combustion. Therefore, it is necessary to use the renewable energy sources for reducing the conventional energy consumption regarding electricity generation. This paper presents an intelligent switch to combine both energy resources, i.e., the solar panels as the renewable energy with the conventional energy from the State Electricity Enterprise (PLN). The artificial intelligence technology with the back-propagation neural network was designed to control the flow of energy that is distributed dynamically based on renewable energy generation. By the continuous monitoring on each load and source, the dynamic pattern of the intelligent switch was better than the conventional switching method. The first experimental results for 60 W solar panels showed the standard deviation of the trial at 0.7 and standard deviation of the experiment at 0.28. The second operation for a 900 W of solar panel obtained the standard deviation of the trial at 0.05 and 0.18 for the standard deviation of the experiment. Moreover, the accuracy reached 83% using this method. By the combination of the back-propagation neural network with the observation of energy usage of the load using wireless sensor network, each load can be evenly distributed and will impact on the reduction of conventional energy usage.

1. Introduction
Currently, almost all of the energy used depends on conventional energy derived from fossil fuels which are resulting in the release of greenhouse gases such as carbon dioxide, methane, and nitrous oxide into the atmosphere increasing the ambient temperature and causing the climate change. Linearly, the higher temperatures give a severe impact on the demand for the electricity consumption regarding the peak electricity and the total electricity. To satisfy the demand, the need to build the additional power plants can increase the cost of electricity generation [1]. In fact, the global power consumption is projected to grow from 18 trillion kWh in 2006 to 32 trillion KWh by 2030. It means that there will be 4800 GW of new power plants to be developed and more than half of it is coming from the developing countries [2]. Unfortunately, the increase of electricity generation accounts for approximately 24% of the greenhouse gases emissions. Therefore, the electricity generation must be realized using the renewable energy to lower the greenhouse gases effect.
The process of electrical energy generation must begin to move from non-renewable energy to renewable energy. Without the contribution from the electricity sector, the significant global carbon emission reductions cannot be realized. The critical changes have begun to take place; for example, the use of renewable energy grew from 16 GW in 2000 to 52 GW in 2006 and will continue to increase in European countries. Targeted in 2050, renewable energy accounts for 50-75% of the total energy used [3].

With the increasing demand for electrical power and the insistence on the use of renewable energy, there is a need to build a system which combines the renewable energy with existing energy. In fact, the smart grids is a power grid that utilizes digital technology which can combine the two types of energy. Smart grids provide electricity using two-way digital communication to control devices from suppliers to the consumer level. There are various components of the smart grid that support the system, one of them is the intelligent power switch (IPS) [3,4].

Intelligent power switch serves to divide the conventional energy and the renewable energy. However, it has a problem related to the absence of the automatic switch that can split the two energy units based on the needs of the load and the generation of renewable energy. The current switch can only solve the breakdown problem that occurs during the change between 2 units of energy used [5]. The principle of dividing the two types of energy is by continuously measuring the battery of solar power; therefore, the system can analyze the current state of the cell [6,7]. The previous research on intelligent switches with two different sources used only one-way working principle, i.e., in a given time, the load is supplied only by one of the generators [8]. However, it only provided a power supply changes to the entire load and did not include artificial intelligence in the switching process. Wireless sensor network (WSN) is now experiencing significant growth due to rapid technological advances. The widespread use of WSN ranges from environmental monitoring, highways, fires, etc. with small to large numbers of users and can also work individually or in groups [9-11].

In this paper, it is proposed that intelligent switches can perform power supply changes against each load used by including the use of artificial intelligence. This article describes the use of artificial intelligence aimed at creating the all-around computing process analogous to the ability of the human brain. In other words, the system can think when the right time to change the switch is. One method of artificial intelligence is the back-propagation neural network approach. Back-propagation method is a learning machine that can perform computation test more quickly. The algorithm is widely used in the control system because the training process is based on simple interconnections, i.e., if the output gives the wrong result, then the weight is corrected. Thus, its error can be minimized, and the next intelligent system response is expected to be close to the correct value [12]. Back-propagation is also capable of fixing the weights in the hidden layer [13]. This method has been used for the control process and has proven reliable [14,15]. By incorporating back-propagation machine learning on switching process and supported by load observation using wireless sensor network, hopefully, the switching process will be better again in merging of both energies. The number of switches can divide when appropriate divide the two energy sources.

2. Methods
An intelligent switch with back-propagation neural network based hybrid power system can determine the load switch pattern according to the available data. At this stage, the switch will be directed to the steps of classification techniques on the load data management and energy sources to find probabilities of the high degree of accuracy and sensitivity. The procedure in making a system using this classification technique consists of several stages.

The first stage was designing the system as shown in Figure 1. The system design was created using two power sources, i.e., solar energy and conventional resources. Each load was connected to the switch, which serves to transfer the energy source that will be used by the load. The switch will communicate with the central processing unit (CPU) via wireless transmission. Communication that occurs between the switch and the CPU is a two-way communication or full duplex. There is an artificial intelligence program that serves to break the power distribution used by the load on the CPU [16]. After creating a
system design, the next process was data collection. The data from the total amount of house load and amount of power obtained from solar energy were collected to be processed into the system. The total daily load was derived from the regular electrical load of the house (amount of daily energy needed by the house). The third stage was preprocessing to improve data accuracy. This stage served as the initial stage of data processing before going into the data classification process. The preprocessing operation was performed by finding the average value of the current obtained from the solar panel in 1 h. Next, the value was normalized; therefore, the back-propagation algorithm will be more accurate. After that, the fourth stage was simulating the data on back-propagation neural network algorithm [17]. In this method, the experiment was performed using inputs consisting of 7 types of load and 2 types of energy sources. The hidden layer used in this algorithm of 15 types and the output amounted to 5 types. The design of the back-propagation neural network is shown in Figure 2. After the data simulation process, the trained algorithm was tested with the test data to see the classification result. Then the data of the classification method test results were analyzed on how accurate the method to be classified.

**Figure 1.** The design of the system is created using two power sources, i.e., solar energy and conventional energy.

**Figure 2.** The design of the back-propagation neural network hybrid power system.

3. Result and discussion
After the experiment process, the data was tested against the back-propagation neural network. The network was tested using 24 data. The results of the network test are shown in Table 1. The table shows the comparison between the desired target for the results obtained from the back-propagation network output.

In Table 1, the first column describes the time (24 h), then the second column describes the condition of the switch on the load 1 (bathroom lamp). The bathroom lamp has a fractional value; it is carried out with a threshold value of 0.5. If the value obtained is more than 0.5, it will be considered as "1" as well if the value obtained less than 0.5 will be considered as "0". By comparing target and results of switch condition, it can be seen that there are some errors in classifying the switch. For example, the bathroom lamp at time 1.00 and 2.00 has a switch condition "0", whereas the target is "1". Time at 5 h has a switch condition "1" whereas the condition target is "0". Contrarily, the garden lamp (load 2) has no error in the process of classification, the result of the target with the output of back-propagation neural network method is similar from at 23.00 until 17.00, and the switch condition is "0"; otherwise at 18.00 until 22.00 the garden lamp has a switch condition "1". One of the results of the back-propagation neural network is shown in Figure 3.
Figure 3. Application results of the back-propagation neural network system.

Table 1. The results of 60 W solar panel experiment

| Time | Load 1 (bathroom lamp) | Load 2 (garden lamp) | Load 3 (bedroom lamp) | Load 4 (kitchen lamp) | Load 5 (living room lamp) | Load 1 (bathroom lamp) | Load 2 (garden lamp) | Load 3 (bedroom lamp) | Load 4 (kitchen lamp) | Load 5 (living room lamp) |
|------|------------------------|----------------------|-----------------------|-----------------------|----------------------------|------------------------|----------------------|-----------------------|-----------------------|----------------------------|
| 1    | 1                      | 0                    | 0                     | 0                     | 0                          | 0.448                  | 0.152                | 0.112                 | 0.004                 | 0.152                     |
| 2    | 1                      | 0                    | 0                     | 0                     | 0                          | 0.474                  | 0.139                | 0.102                 | 0.004                 | 0.139                     |
| 3    | 1                      | 0                    | 0                     | 0                     | 0                          | 0.500                  | 0.126                | 0.092                 | 0.003                 | 0.126                     |
| 4    | 1                      | 0                    | 0                     | 0                     | 0                          | 0.525                  | 0.114                | 0.081                 | 0.003                 | 0.114                     |
| 5    | 0                      | 0                    | 0                     | 0                     | 0                          | 0.700                  | 0.309                | 0.534                 | 0.000                 | 0.309                     |
| 6    | 1                      | 0                    | 0                     | 0                     | 0                          | 0.724                  | 0.325                | 0.546                 | 0.000                 | 0.325                     |
| 7    | 1                      | 0                    | 1                     | 0                     | 0                          | 0.748                  | 0.342                | 0.559                 | 0.000                 | 0.342                     |
| 8    | 0                      | 0                    | 0                     | 0                     | 0                          | 0.012                  | 0.247                | 0.161                 | 0.002                 | 0.247                     |
| 9    | 0                      | 0                    | 0                     | 0                     | 0                          | 0.005                  | 0.197                | 0.129                 | 0.000                 | 0.197                     |
| 10   | 0                      | 0                    | 0                     | 0                     | 0                          | 0.000                  | 0.144                | 0.095                 | 0.002                 | 0.144                     |
| 11   | 0                      | 0                    | 0                     | 0                     | 0                          | 0.005                  | 0.090                | 0.061                 | 0.005                 | 0.090                     |
| 12   | 0                      | 0                    | 0                     | 0                     | 0                          | 0.009                  | 0.036                | 0.026                 | 0.007                 | 0.036                     |
| 13   | 0                      | 0                    | 0                     | 0                     | 0                          | 0.015                  | 0.016                | 0.007                 | 0.009                 | 0.016                     |
| 14   | 0                      | 0                    | 0                     | 0                     | 0                          | 0.022                  | 0.066                | 0.040                 | 0.011                 | 0.066                     |
| 15   | 0                      | 0                    | 0                     | 0                     | 0                          | 0.034                  | 0.105                | 0.065                 | 0.013                 | 0.105                     |
| 16   | 0                      | 0                    | 0                     | 0                     | 0                          | 0.055                  | 0.127                | 0.081                 | 0.013                 | 0.127                     |
| 17   | 0                      | 0                    | 0                     | 0                     | 0                          | 0.079                  | 0.144                | 0.094                 | 0.012                 | 0.144                     |
| 18   | 1                      | 1                    | 1                     | 0                     | 1                          | 0.887                  | 0.765                | 0.839                 | 0.013                 | 0.765                     |
| 19   | 1                      | 1                    | 1                     | 1                     | 1                          | 0.958                  | 1.041                | 1.019                 | 1.011                 | 1.041                     |
| 20   | 1                      | 1                    | 1                     | 1                     | 1                          | 1.010                  | 1.003                | 0.999                 | 1.007                 | 1.003                     |
| 21   | 1                      | 1                    | 1                     | 0                     | 1                          | 1.035                  | 0.663                | 0.788                 | 0.002                 | 0.663                     |
| 22   | 1                      | 1                    | 1                     | 0                     | 1                          | 1.081                  | 0.637                | 0.776                 | 0.002                 | 0.637                     |
| 23   | 1                      | 0                    | 0                     | 0                     | 0                          | 0.977                  | 0.202                | 0.158                 | 0.003                 | 0.202                     |
| 24   | 1                      | 0                    | 0                     | 0                     | 0                          | 1.003                  | 0.214                | 0.168                 | 0.004                 | 0.214                     |
The target in Figure 3 shows the standard deviation at 0.24 from the desired target. The \( x \)-axis in Figure 3 represents the number of the switch to be classified, i.e., switch at load 1, at load 2, at load 3, at load 4 and at load 5. The \( y \)-axis represents the classification result. The target in Figure 3 represents the target in red color \([1 \ 1 \ 1 \ 0 \ 1]\), whereas the result of the test is illustrated by blue color \([0.88 \ 0.76 \ 0.84 \ 0.014 \ 0.76]\).

The test result is running the back-propagation method using data that was never used before. Figure 3 illustrates when the switch of load 1 shows the classification result at 0.88. Therefore, it has a standard deviation of 0.12 from the target on the switch of load 1 which has a value at 1. When the switch of load 3 shows the classification result at 0.84; therefore, it has a standard deviation at 0.16 of the target on the switch of load 3 which has a value at 1. Moreover, the switch of load 5 shows the classification results at 0.76; therefore, it has a standard deviation at 0.24 from the target on the switch of load 5 which has a value at 1. In this test, the maximum distance between switches that have been installed wirelessly was measured from each transmission power change and the baud rate (Table 2).

| Power (dBm) | LOS 9600 | LOS 2400 | NLOS 9600 | NLOS 2400 |
|-------------|----------|----------|-----------|-----------|
| -1          | 1.7      | 2.9      | 1.3       | 2.2       |
| 2           | 2.9      | 4.8      | 2.1       | 3.6       |
| 5           | 4.4      | 6.9      | 3.3       | 5.2       |
| 8           | 7.6      | 11.5     | 5.8       | 8.7       |
| 11          | 9.1      | 13.9     | 6.8       | 10.5      |
| 14          | 16.7     | 24.5     | 12.6      | 18.4      |
| 17          | 21.1     | 30.8     | 15.9      | 23.2      |
| 20          | 35.6     | 51.1     | 26.8      | 38.5      |

Power transmission in units of mW was increased 100% every 3 dBm increase. In comparison with the rise in the measured distance, the result was only increased 50%. The ratio of distance to power is different from the distance ratio to the baud rate. Comparison of baud rate with distance was inversely proportional, the lower the baud rate used, the higher the range of the resulting range. It results from the effect of baud rate changes at HC-12 radio frequency which affects the receiver sensitivity.

| Table 3. Relationship of baud rate with sensitivity |
|--------------------------------------------------|
| Baud Rate | 2400 | 9600 |
| Receiver Sensitivity (dBm) | -117 | -112 |

The higher the baud rate, the higher the receiver sensitivity. The receiver sensitivity is the minimum power of signal strength that the receiver can accept, and the signal strength will decrease with distance [18]. Therefore, the lower the receiver sensitivity, the longer the distance range will be.

4. Conclusion

In this study, it can be concluded that the HC-12 transmitter shows a good transmit distance. The obtained value was a minimum distance of 1.7 m and a maximum distance of 51.1 m. It is useful when observing the use of electrical energy at the house equipment. In the experiment of the back-propagation neural network, the standard deviation was at 0.28; therefore, the accuracy obtained was 83%. By the combination of the back-propagation neural network with the observation of energy usage of the load using wireless sensor network, it leads to the power distribution process at each load which can be evenly distributed. Moreover, it will have a positive impact on the reduction of conventional energy usage.
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